FOREWORD

In the past the passenger vehicle market was almost exclusively occupied by gasoline engine vehicles.

However, because of the world-wide fuel and economic conditions, almost all automobile manufacturers have developed diesel engine passenger vehicles, and it is expected that the demand for diesel engine vehicles will continue to increase.

To decrease the size and weight of the fuel injection pump, "the heart of the engine", the VE (distributor) type injection pump has been adopted, instead of the conventional PE (in-line) type pump.

Moveover, different kinds of additional devices for the VE type pump have also been developed, in order to improve the "feeling" of the diesel engine to that of the gasoline engine.

This service manual describes the construction and operation of each additional device used on the VE type injection pump.

For repair and maintenance procedures, please refer to our service manual, "ADDITIONAL DEVICES' REPAIR, SERVICE & MAINTENANCE".

BOOST COMPENSATOR (B.C.S.)

Some engines are equipped with a turbocharger to provide an increase in engine output over engines of the same displacement.

Basic turbocharger performance is as follows.
An exhaust gas turbine is rotated at high speed by the engine's exhaust gas. This rotation is transmitted to the intake turbine shown in Fig. 1.

Consequently the amount of air supplied to the intake manifold, and therefore the combustion chamber, is increased.
In accordance with this increased supply of air to the combustion chamber, the fuel injection quantity must also be increased to maintain a constant fuel-air ratio for optimum combustion, i.e., optimum engine output.

This increase in fuel injection quantity is accomplished by utilizing the boost pressure obtained through the air suction at the intake manifold.

The boost compensator has been developed to match fuel injection pump operation with turbocharger operation in order to provide an increase in engine output over engines of the same displacement.
This boost compensator is referred to as "B.C.S." in the following explanation.

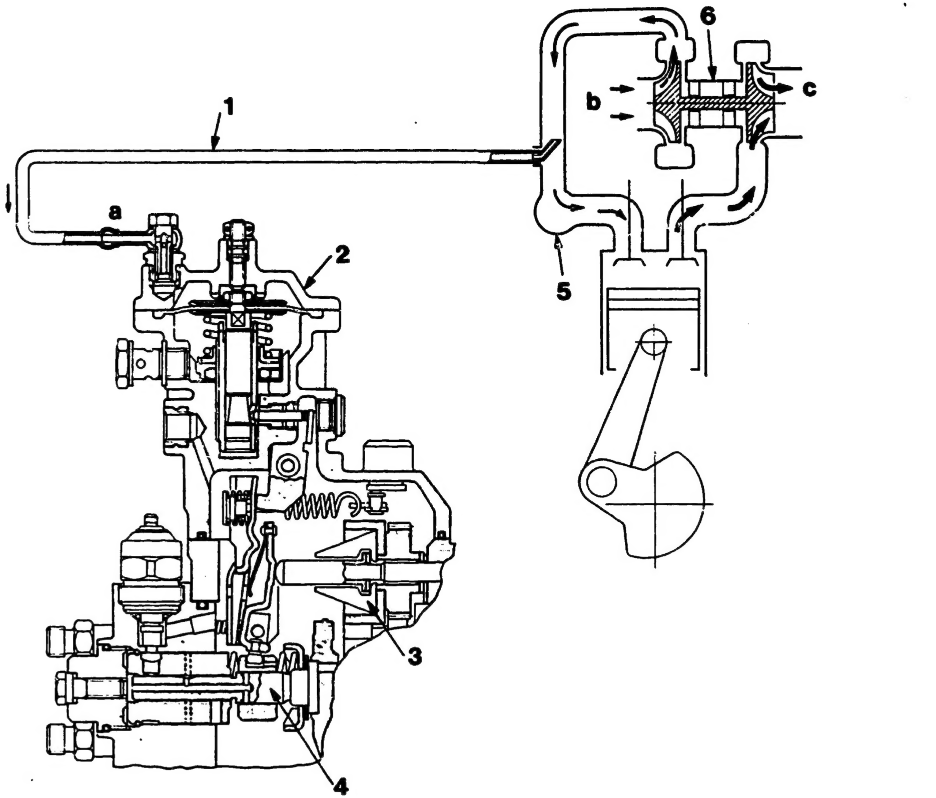


Fig. 1 Boost compensator and turbocharger

1 = Connecting pipe
2 = Boost compensator
3 = Flyweight
4 = Plunger

5 = Intake manifold
6 = Turbocharger

a = Boost pressure inlet
b = Suction
c = Exhaust

Construction

Fig. 2 shows the construction of the B.C.S. and related VE pump components.

A diaphragm is installed in the upper portion of the B.C.S. Boost pressure supplied to the pressure chamber acts on the upper side of the diaphragm.
The B.C.S. spring is installed below the diaphragm.
The adjusting pin is connected directly to, and moves together with, the diaphragm.
The tapered portion of the adjusting pin contacts a pin, the opposite end of which contacts the B.C.S. lever.
The opposite end of B.C.S. lever then contacts the VE pump tension lever.

The upper portion of the tension lever is attached to the governor spring, which is connected to the control lever.
The lower portion of the tension lever engages the control sleeve.
Diaphragm and therefore adjusting pin movement result in movement of the pin.
This movement is then transmitted to the B.C.S. lever which, pivotting around the B.C.S. lever pin, moves the tension lever.
Movement of the tension lever then results in control sleeve movement.

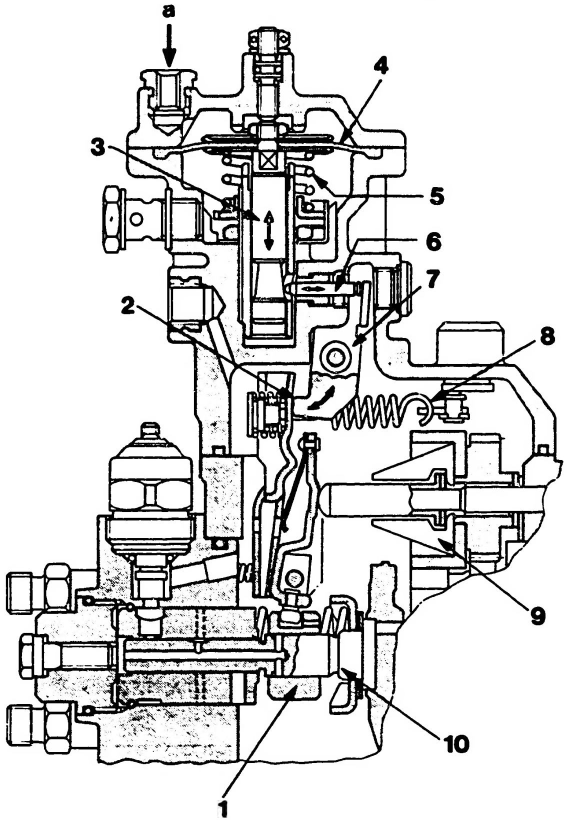


Fig. 2 Cross-sectional view of the B.C.S.

1 = Control sleeve
2 = Tension lever
3 = Adjusting pin
4 = Diaphragm
5 = B.C.S. spring
6 = Pin
7 = B.C.S. lever
8 = Governor spring
9 = Flyweight
10 = Plunger

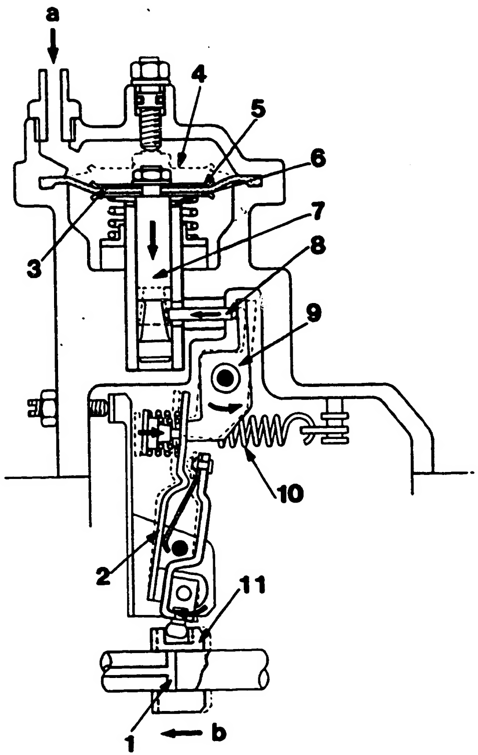
a = Boost pressure inlet

Operation

Fig. 3 shows B.C.S. operation.
When the boost pressure is below P_1, shown in Fig. 3, due to low engine speed and a light load on the engine, the diaphragm does not move because of the B.C.S. spring force.

As the boost pressure increases and exceeds P_1, the diaphragm gradually compresses the B.C.S. spring and the adjusting pin is moved downward. Because of this, the pin in contact with the tapered portion of the adjusting pin moves to the left.
The B.C.S. lever moves counterclockwise around its supporting pin, allowing the tension lever to be pulled clockwise by the governor spring.

Consequently the control sleeve is moved to the left (i.e. in the fuel increase direction as shown by the solid line in Fig. 4), and the fuel injection quantity is increased in accordance with the increase in boost pressure.
As the boost pressure further increases to P_2 (Fig. 4), the adjusting pin contacts the spacer, which limits the boost compensation stroke.
The adjusting pin cannot move past this point, despite any further increase in the boost pressure.



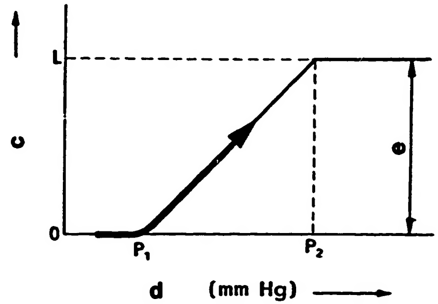
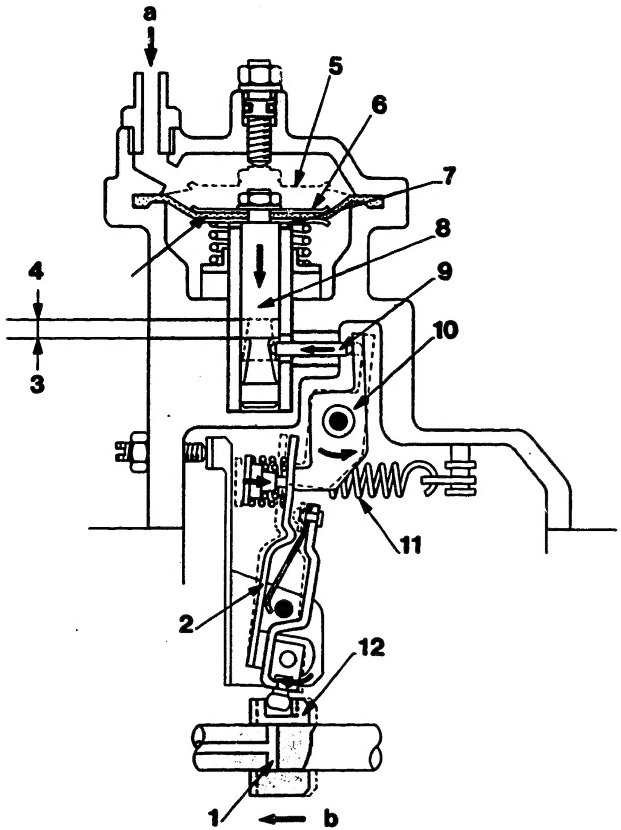


Fig. 3 B.C.S operation (when boost pressure is below P_2)

1 = Cut-off port
2 = Tension lever
3 = Diaphragm
4 = Boost pressure: below P_1
5 = Boost pressure: above P_2
6 = Spacer
7 = Adjusting pin
8 = Pin
9 = B.C.S. lever
10 = Governor spring
11 = Control sleeve

a = Boost pressure
b = Fuel increase direction
c = Adjusting pin stroke (mm)
d = Boost pressure
e = Boost compensation stroke



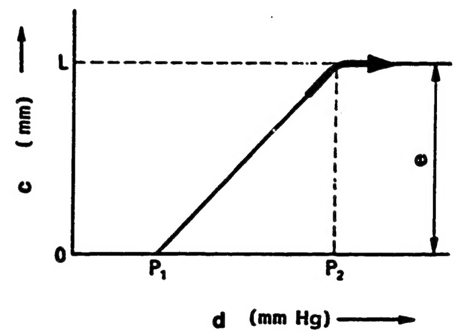


Fig. 4 B.C.S. operation (when boost pressure is P_2 or above)

1 = Cut-off port
2 = Tension lever
3 = B.C.S. stroke
4 = Diaphragm
5 = Boost pressure: below P_1
6 = Boost pressure: above P_2
7 = Spacer
8 = Adjusting pin
9 = Pin
10 = B.C.S. lever
11 = Governor spring
12 = Control sleeve
a = Boost pressure
b = Fuel increase direction
c = Adjusting pin stroke
d = Boost pressure
e = Boost compensation stroke

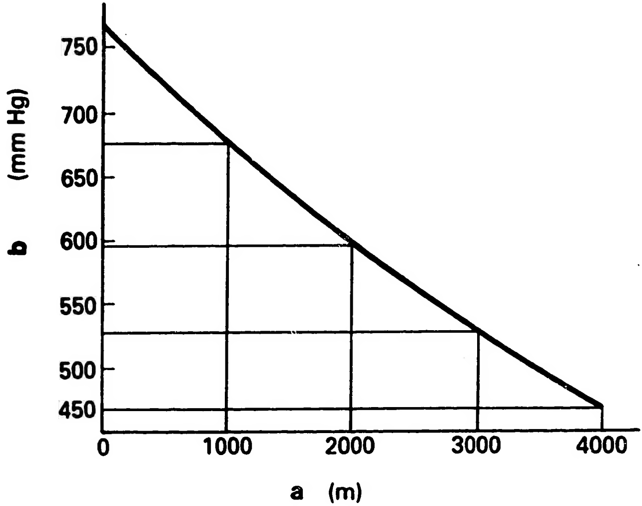


Fig. 5 Relationship between atmospheric pressure and altitude

a = Altitude
b = Atmospheric pressure

ANEROID COMPENSATOR (A.C.S.)

Purpose

Fig. 5 shows the relationship between atmospheric pressure and altitude.
Atmospheric pressure decreases as altitude increases.

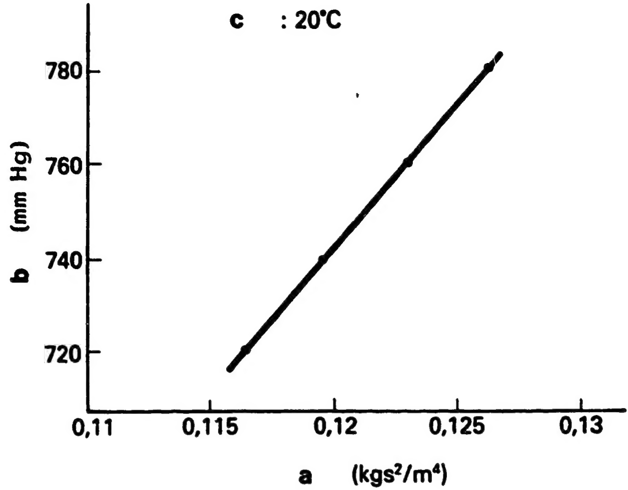


Fig. 6 Dry air density

a = Density
b = Atmospheric pressure
c = Air temperature

Fig. 6 shows the relationship between atmospheric pressure and air density. Air density decreases as the atmospheric pressure decreases.
As mentioned previously, a vehicle with a diesel engine adjusted to function at low altitudes may experience the following problems due to excessive fuel injection when used at high altitudes:

1. Increased emission of black smoke.
2. Insufficient engine output, despite increased fuel consumption.
3. Carbon deposits in the combustion chamber (thus shortening the service life of the engine).

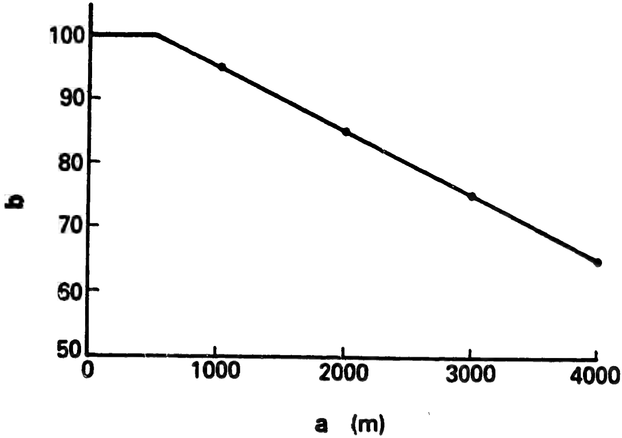


Fig. 7 Relationship between full-load injection quantity and altitude

a = Altitude
b = Full-load injection quantity (%)

In order to prevent the above problems, the full-load fuel injection quantity must be adjusted to compensate for altitude, as shown in Fig. 7.

The aneroid compensator moves the tension lever via the adjusting pin as the atmospheric pressure changes, allowing the control sleeve to alter the full-load injection quantity.

Construction

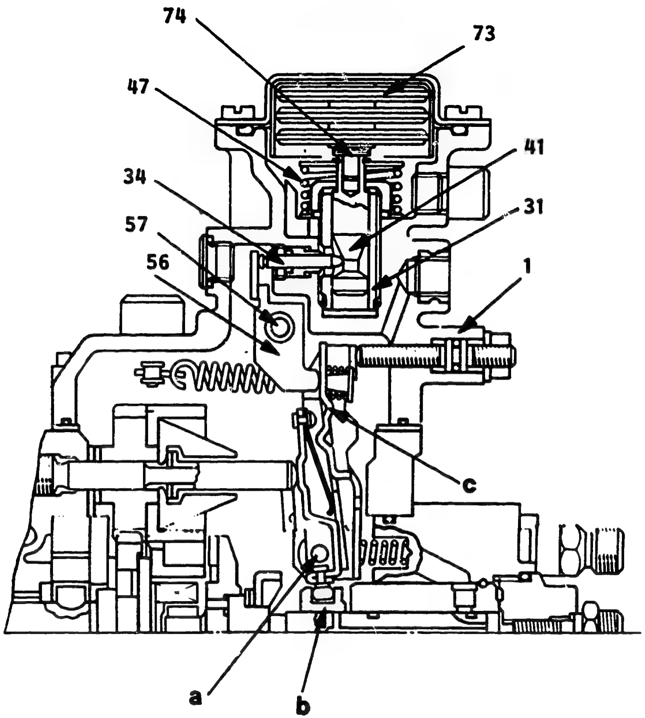
Fig. 8 shows a cross-sectional view of the aneroid compensator equipped VE type injection pump.
The aneroid compensator is mounted on the top of the VE type pump.
The inside of the aneroid compensator housing (governor cover) is at atmospheric pressure.
The aneroid compensator consists of the following main parts: bellows (73), aneroid compensator spring (47), adjusting pin (41), pin (34), aneroid compensator lever (56), screw bushing (31).
The bellows is attached to the adjusting pin via adjusting shims, and is held against the cover by the set force of the aneroid compensator spring.
The tapered portion of the adjusting pin contacts a pin, the opposite end of which contacts the A.C.S. lever.

The opposite end of the A.C.S. lever then contacts the VE pump tension lever.
The upper portion of the tension lever is attached to the governor spring, which is connected to the control lever.
The lower portion of the tension lever engages the control sleeve.
Bellows and therefore adjusting pin movement result in movement of the pin.

This movement is then transmitted to the A.C.S. lever which, pivotting around the A.C.S. lever pin, moves the tension lever.
Movement of the tension lever then results in control sleeve movement.
Movement of the tension lever then results in control sleeve movement.

As altitude increases and atmospheric pressure decreases, the bellows (73) expands and pushes the adjusting pin (41) downwards.
The pin (34) contacting the adjusting pin will therefore push the A.C.S. lever (56) to the left, as shown in Figure 9.

Pivotting around point A, the A.C.S. lever then moves the top of the tension lever to the right.
Tension lever movement around pivot point B will then move the control sleeve in the fuel decrease direction.



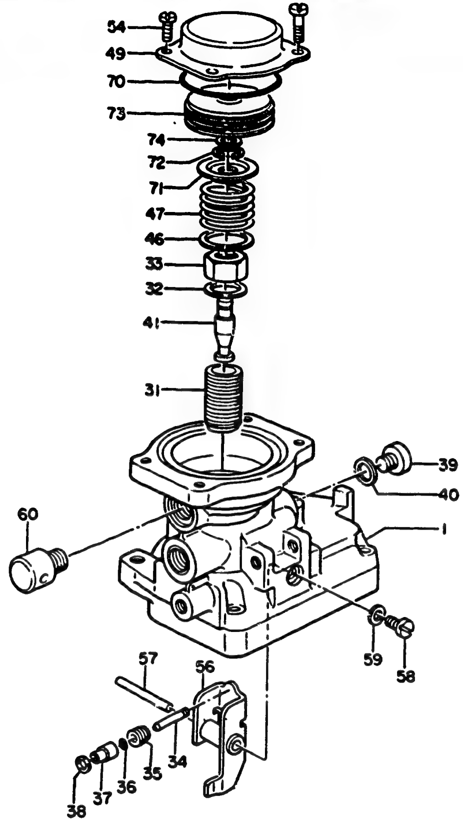
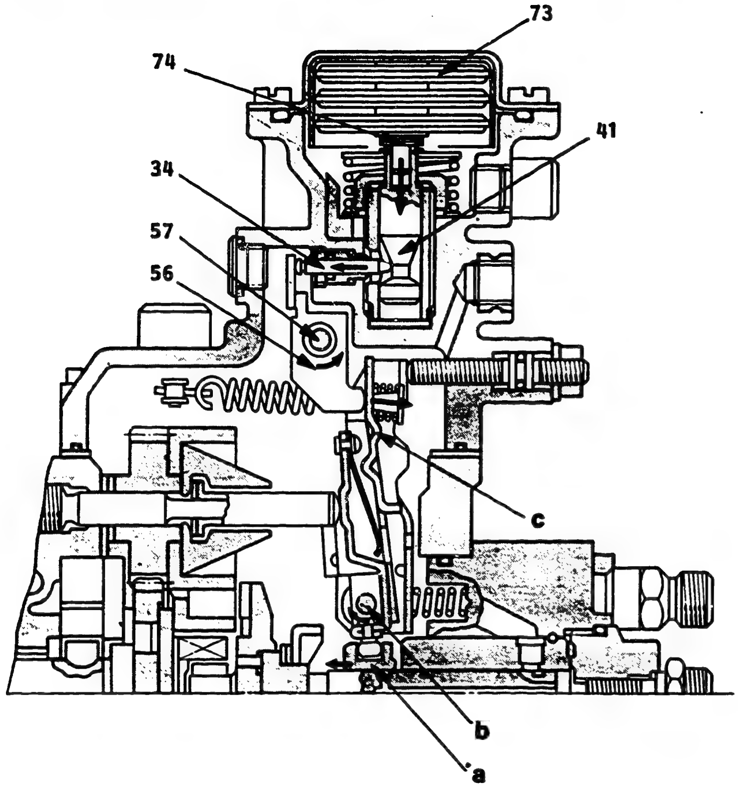


Fig. 8 Cross-sectional of the A.C.S.

1 = Governor cover
31 = Screw bushing
34 = Pin
41 = Adjusting pin
47 = Spring

56 = Lever
57 = Pivot A
73 = Bellows (vacuum)
74 = Shim

a = Pivot B
b = Control sleeve
c = Tension lever



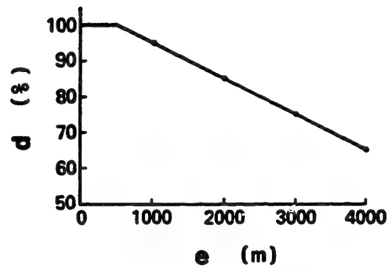


Fig. 9 A.C.S. operation (as atmospheric pressure decreases)

34 = Pin
41 = Adjusting pin
56 = Lever
57 = Pivot A

73 = Bellows (vacuum)
74 = Shim
a = Control sleeve
b = Pivot B
c = Tension lever

d = Full-load injection quantity
e = Altitude

Construction

The Aneroid and Boost Compensator incorporates the Boost Compensator and the Aneroid Compensator.
With the A.B.C.S., the injection quantity is increased proportionately to the boost pressure, thereby increasing the engine output.
At high altitudes the full-load injection quantity is decreased to prevent the emission of black smoke, to decrease carbon deposits in the engine's combustion chamber.

In the A.B.C.S., what was the atmospheric chamber of the B.C.S. (where the boost compensator spring is located) is connected to a regulator through one of the regulator's two nipples.

The other nipple, with a 0.6 mm diameter orifice, is connected to the vacuum pump. The regulator is also fitted with a bellows and a valve.

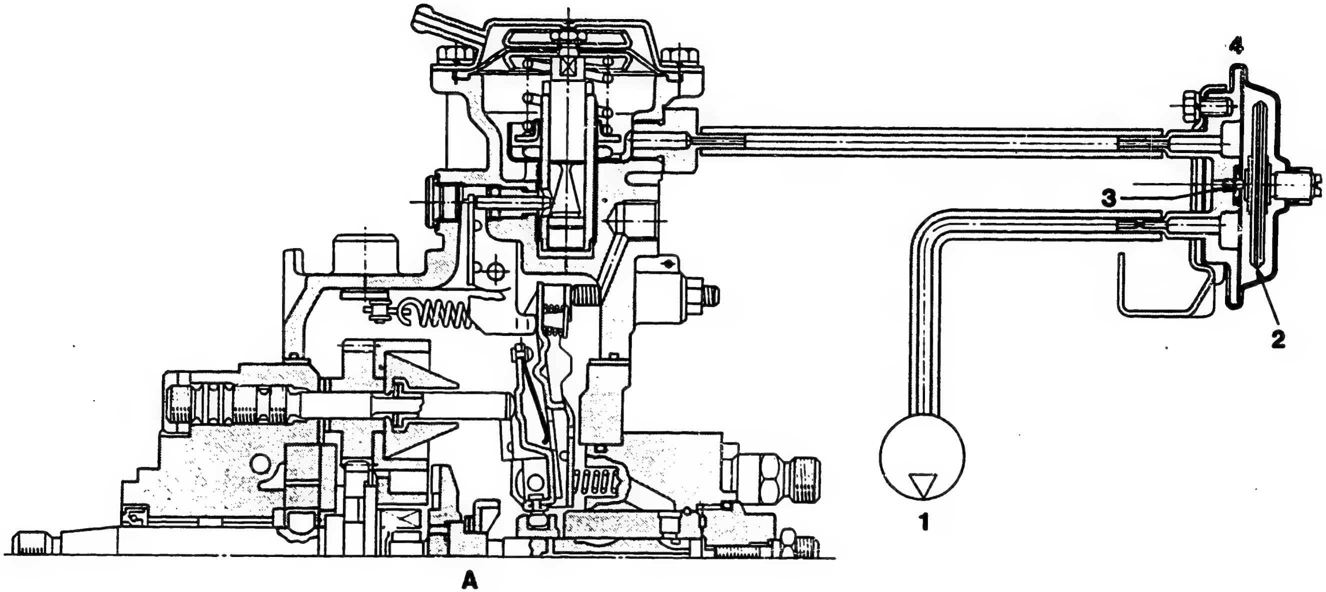


Fig. 10 Cross-sectional view of the A.B.C.S. and vacuum regulator

1 = Vacuum pump   2 = Bellows   3 = Valve   4 = Vacuum regulator

A = A.B.C.S.

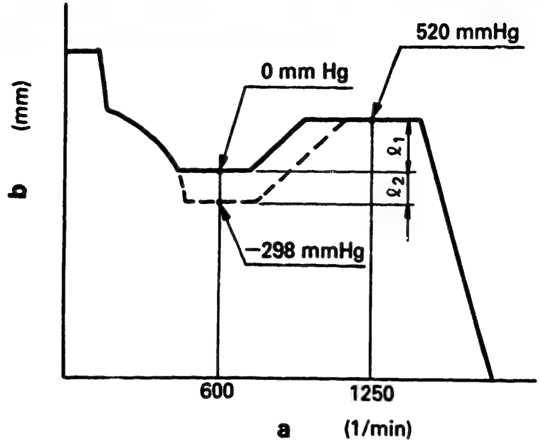


Fig. 11 A.B.C.S. performance (control sleeve position/pump speed)

ℓ_1: B.C.S. stroke
ℓ_2: A.C.S. stroke

a: Pump speed (rpm)
b: Control sleeve position

Operation

As shown in Figs. 11 and 12, the B.C.S. is activated when the boost pressure exceeds 0 mmHg.

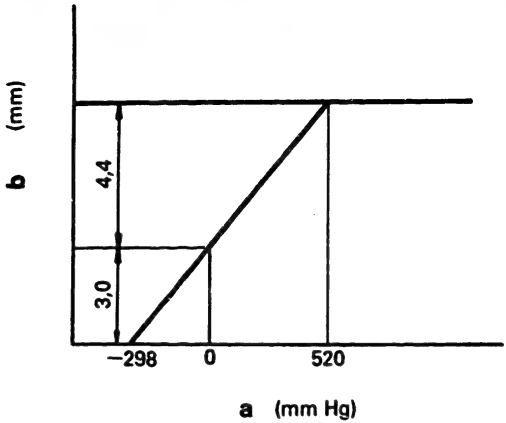


Fig. 12 A.B.C.S. performance (adjusting pin stroke/boost pressure)

a = Boost pressure
b = Adjusting pin stroke

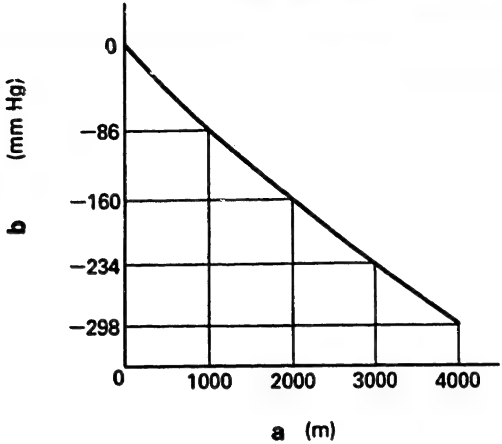


Fig. 13 Relationship between atmospheric pressure and altitude

a = Altitude
b = Atmospheric pressure

During high altitude operation the atmospheric pressure and the boost pressure will vary in accordance with the altitude, as shown in Figs. 13 and 14.

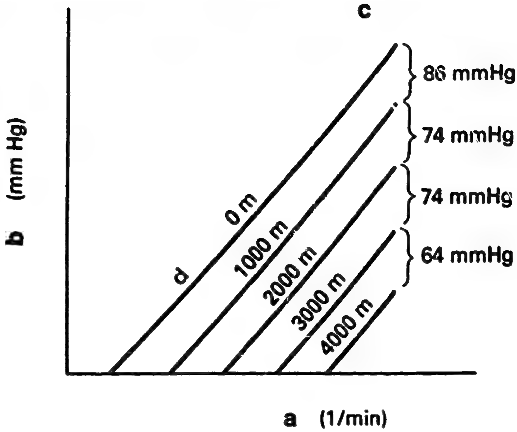


Fig. 14 Relationship between boost pressure and pump speed

a = Pump speed (rpm)
b = Boost pressure
c = Pressure difference
d = Altitude

With the former B.C.S., when the boost pressure decreased with altitude (as shown in Fig. 14), the corresponding boost compensator chamber pressure also decreased (as shown in Fig. 13) and could therefore not reduce the full-load injection quantity. However, with the A.B.C.S. the boost compensator chamber pressure is maintained at 410 mmHg abs and therefore when the boost pressure decreases, the boost compensator spring pushes the diaphragm up to reduce the full-load injection quantity. (Fig. 15)

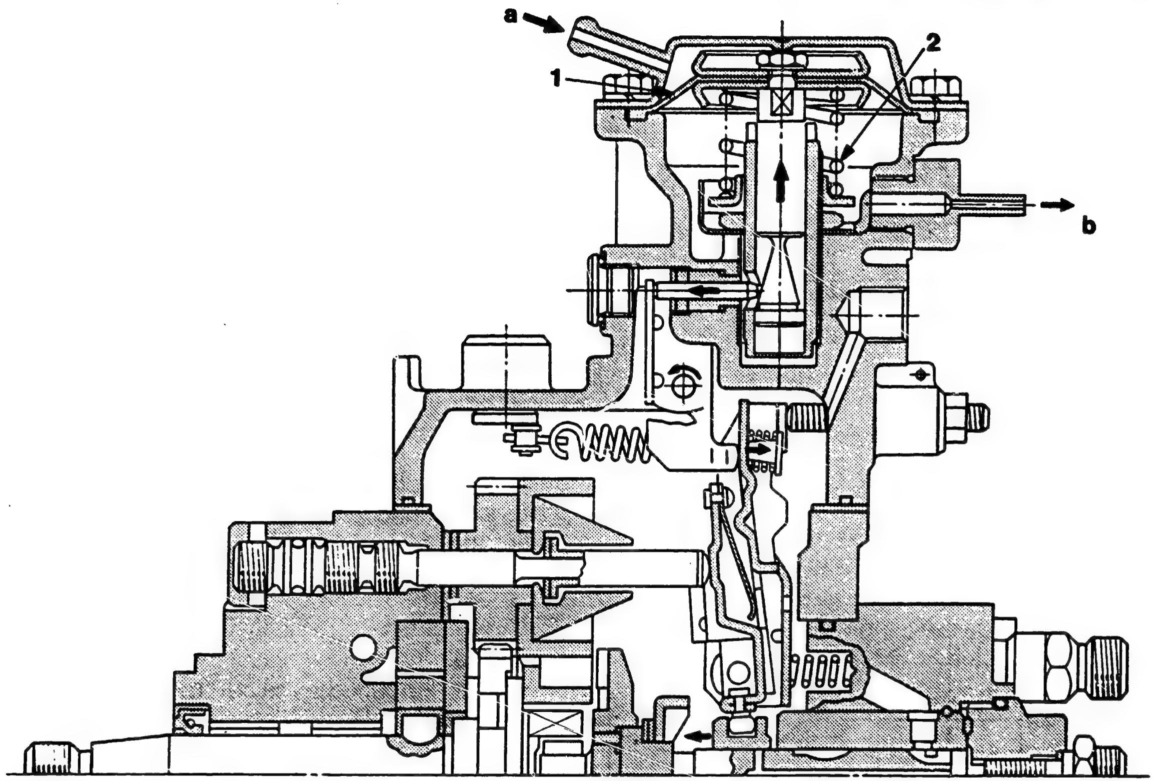


Fig. 15 A.B.C.S. operation

1 = Diaphragm
2 = Boost compensator spring

a = From turbocharger
b = To regulator (410 mmHg abs)

Whatever the altitude, the regulator maintains a constant output pressure of 410 mmHg abs when the input pressure from the vacuum pump is less than 260 mmHg abs. Air is sucked in through the ball valve, maintaining the output side pressure. (Fig. 16)

1. When output side pressure has decreased. The bellows expands, pushes against the ball valve, and outside air flows into the regulator. When the set pressure of 410 mmHg abs is reached, the bellows contracts and the ball valve is closed. (Fig. 17)

2. When output side pressure has increased. The bellows contracts, separates from the ball valve, and the pressure inside the regulator is decreased by the input side's vacuum pump. The regulator then returns to the condition described in "1." above. (Fig. 18)

Note: Absolute pressure of 260 mmHg is equal to −500 mmHg at sea level, and similarly, 410 mmHg a.b.s. is equal to −350 mmHg at sea level.

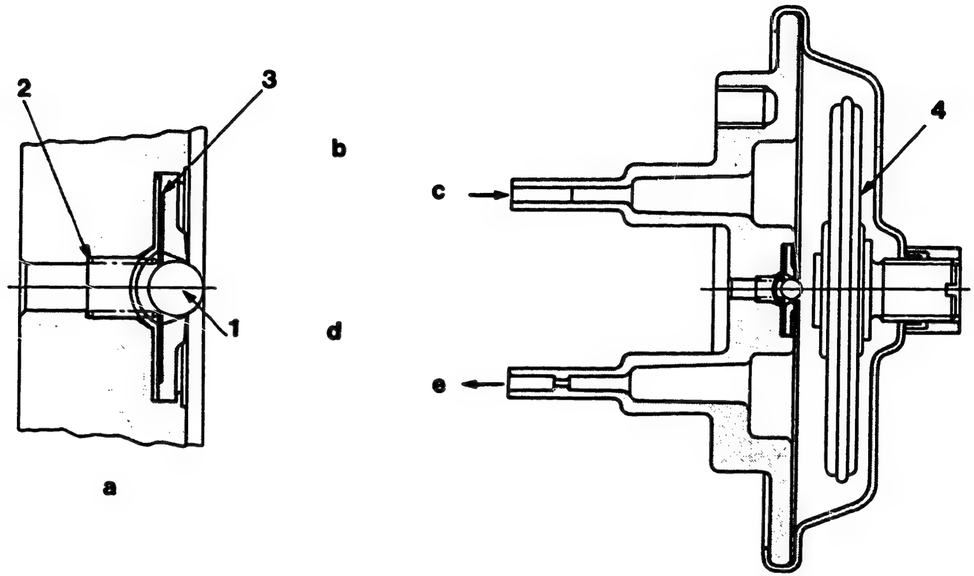


Fig. 16 Cross-sectional view of the vacuum regulator

1 = Valve
2 = Spring
3 = Seat
4 = Bellows

a = Seat portion
b = Output pressure: 410 mmHg abs (constant)
c = To atmospheric chamber of B.C.S.
d = Input pressure: less than 260 mmHg abs
e = From vacuum pump

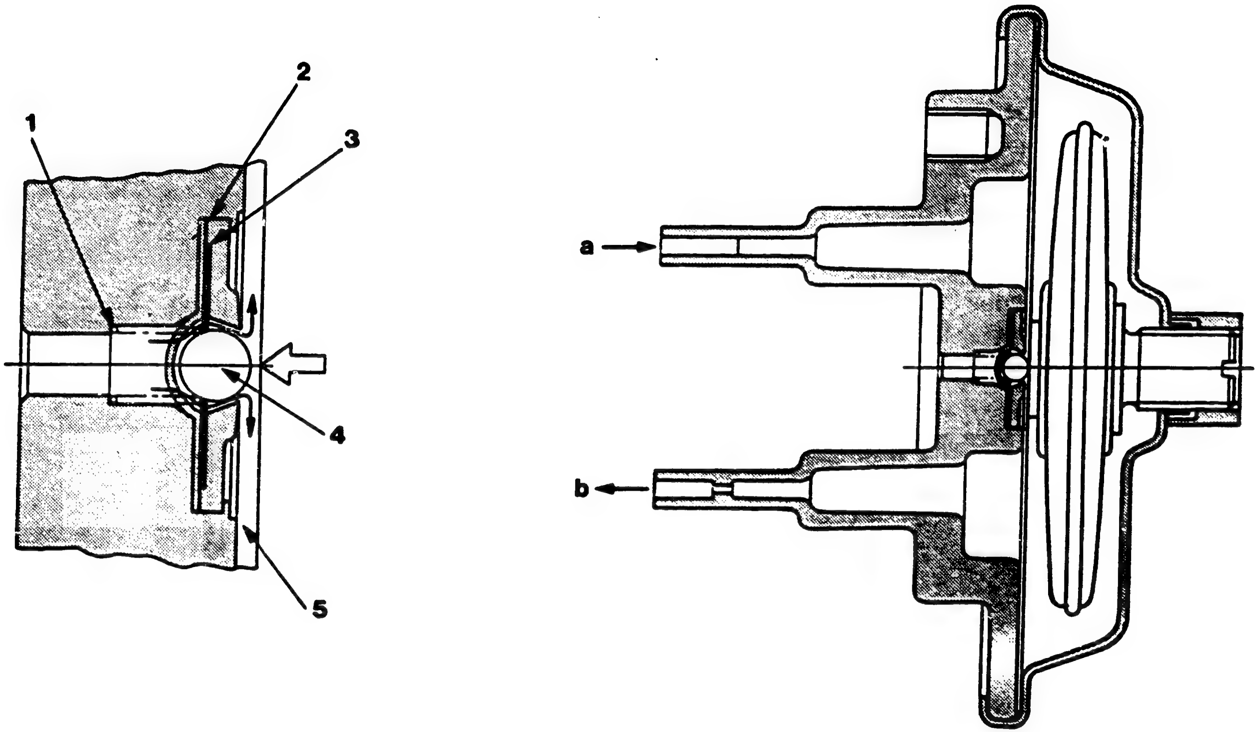
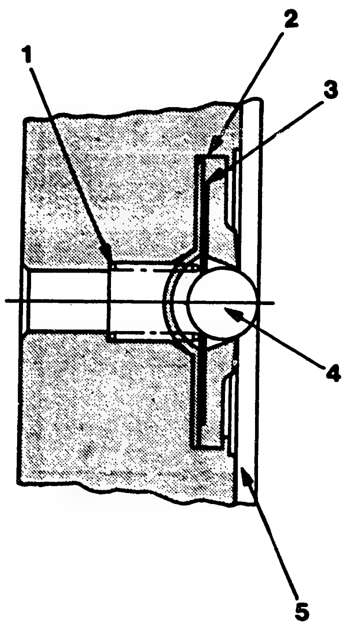


Fig. 17 Regulator operation

1 = Spring
2 = Membrane
3 = Seat
4 = Ball valve

5 = Bellows pushes against ball valve

a = Output
b = Input



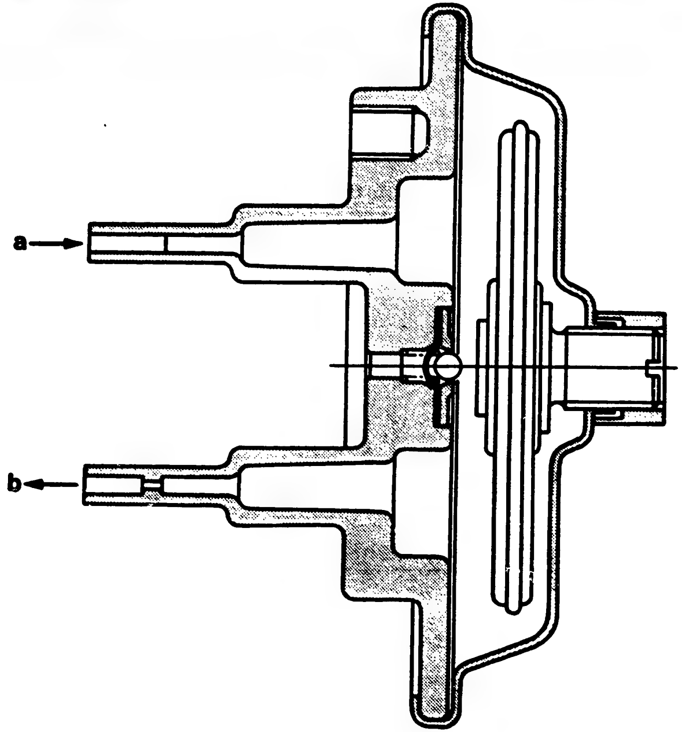


Fig. 18 Regulator operation

1 = Spring
2 = Membrane
3 = Seat
4 = Ball valve

5 = The ball valve and the bellows separate and the ball valve is closed.

a = Output
b = Input

VACUUM REGULATING VALVE (V.R.V.)

The vacuum regulating valve is installed above the control lever and is connected to the control lever shaft.
The V.R.V. alters the input pressure from the vacuum pump, depending on the control lever position, and thereby controls the opening and closing of the Exhaust Gas Recirculation (E.G.R.) valve.

The E.G.R. system is provided and maintained by the vehicle manufacturer to control NOx emission. It is included in this manual for information purposes only, since some of the control devices mounted on the pump work in conjunction with this system. (Fig. 19)

Construction

As shown in Fig. 20, the V.R.V. is composed of a cam (5) to change the set force of the spring (4) (depending on the control lever (8) position), a needle valve (2) with two seats and a disk (8) (which also serves as a seat for the needle valve), and a diaphragm.

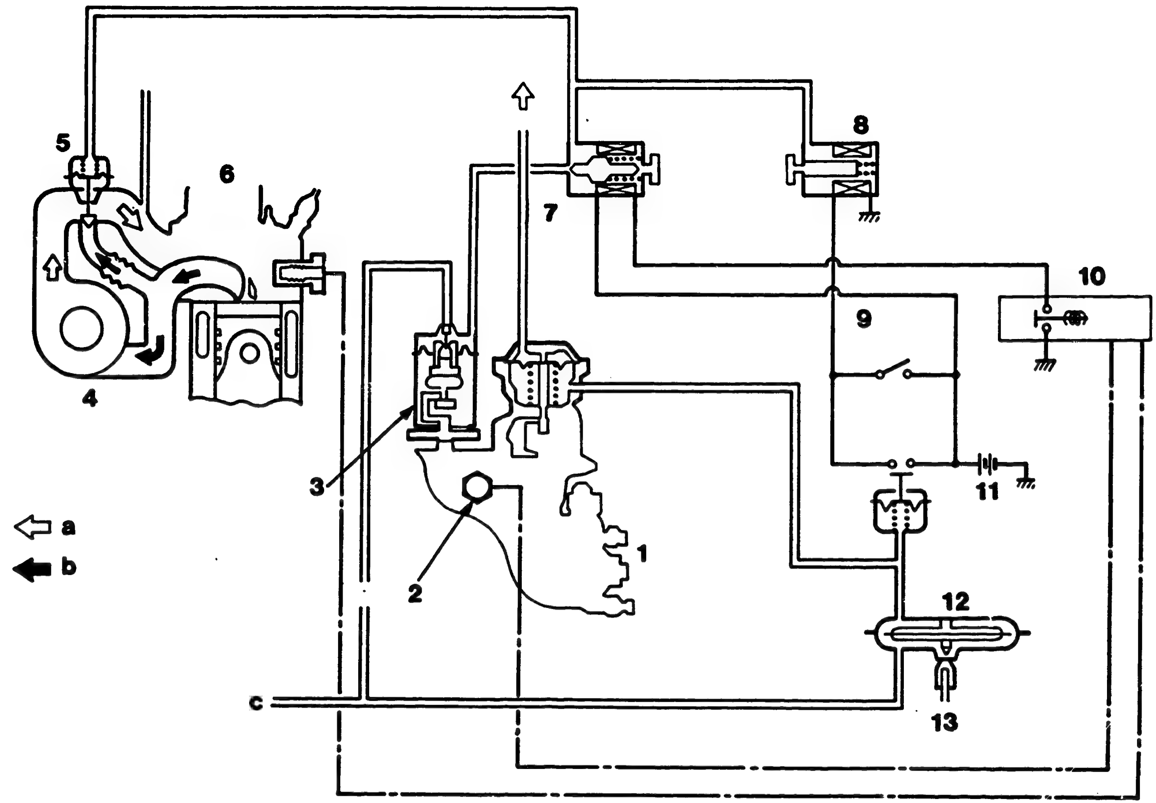
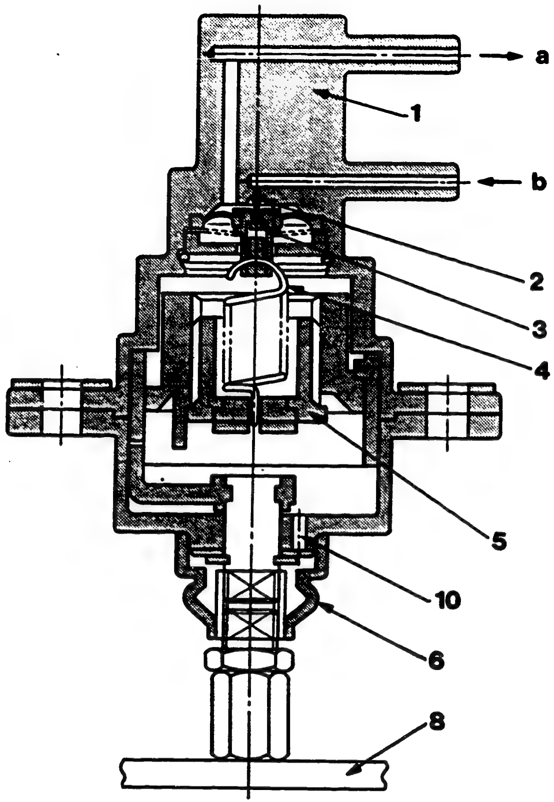


Fig. 19 Exhaust Gas Recirculation (E.G.R. system)

1 = Fuel injection pump
2 = Engine speed sensor
3 = Vacuum regulating valve
4 = Turbocharger
5 = E.G.R. valve
6 = Coolant temp. sensor
7 = E.G.R. control solenoid valve
8 = E.G.R. vacuum reducer solenoid valve
9 = Accelerator switch
10 = E.G.R. control unit
11 = Vacuum switch
12 = Constant pressure valve
13 = Atmospheric pressure
a = Intake air
b = Exhaust gas
c = To vacuum source



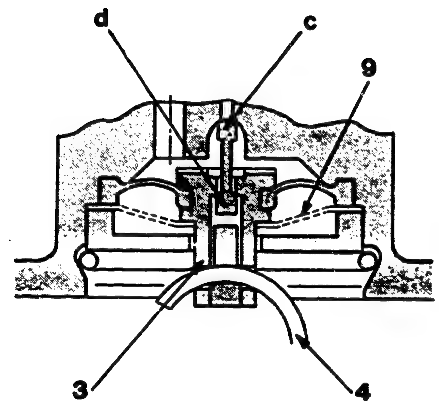


Fig. 20 Cross-sectional view of the V.R.V.

1 = Case
2 = Needle valve
3 = Disk
4 = Spring
5 = Cam

6 = Boots
8 = Control lever
9 = Spring
10 = Ventilation port

a = To E.G.R. valve (output side)
b = From vacuum pump (input side)
c = Valve A
d = Valve B

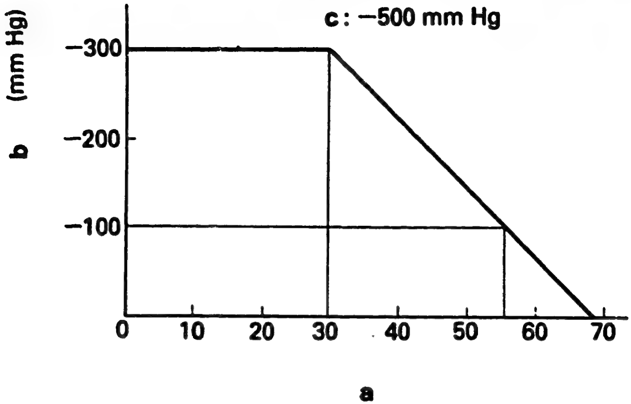


Fig. 21 Negative output pressure characteristics

a = Shaft rotation angle (deg.)
b = Negative output pressure
c = Negative input pressure

Operation

The V.R.V. controls the output pressure by altering the set force of the spring (4) in proportion to the control lever shaft's rotation angle.

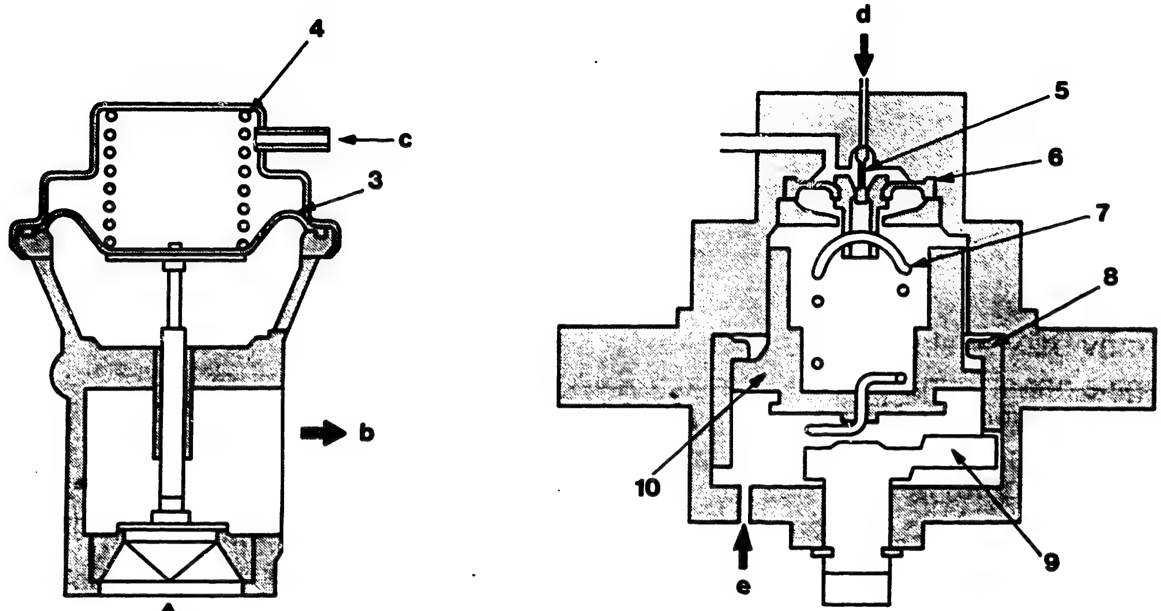


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Fig. 22 E.G.R. control valve and V.R.V.

1 = EGR control valve
2 = Vacuum regulator valve
3 = Diaphragm
4 = Spring
5 = Needle

6 = Diaphragm
7 = Tension spring
8 = Cam ring
9 = Shaft and lever
10 = Cam

a = Exhaust gas inlet
b = Exhaust gas outlet
c = Output pressure
d = Input pressure (from vacuum pump)
e = Atmospheric pressure

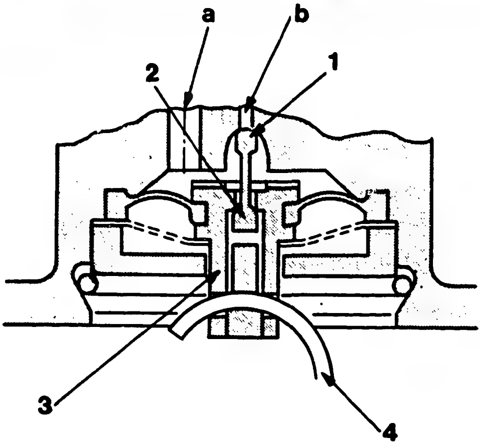


Fig. 23 V.R.V. operation (when output pressure equals the set force of spring (4)

1 = Valve A
2 = Valve B
3 = Disk
4 = Spring

a = Output side
b = Input side

1. As shown in Fig. 23, when the set force of the spring (4) and the output pressure (i.e. negative pressure) are equal, valves A and B are closed and the output pressure is maintained at the set value.

When the set force of the spring (4) equals the output pressure the disk does not move, both valves A and B are closed, and a constant output pressure is maintained.

2. Output pressure increase (approaching atmospheric pressure)

When the output pressure increases, the set force of the spring (4) exceeds the output pressure and pulls the disk (3) downward to open valve A and close valve B. (Fig. 24)
Consequently, the output pressure decreases until it equals the set force of the spring (4).

When the output pressure equals the set force of the spring (4), the disk (3) moves to a position where valves A and B are closed, therefore maintaining the same output pressure as that prior to the change.

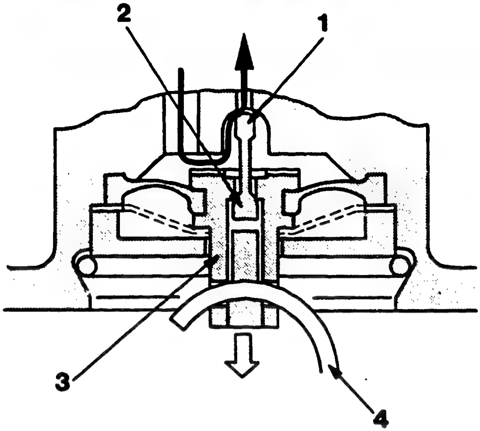


Fig. 24 V.R.V. operation (when output pressure increases)

1 = Valve A
2 = Valve B
3 = Disk
4 = Spring

⇨: Disk movement
The disk is pulled downward by the spring (4); valve A is opened and valve B is closed.
➡: Air flow
The vacuum pump sucks air in from the output side, lowering the output side pressure.

3. Weak spring set force

When the control lever is moved toward the full-speed position, the set force of the spring (4) becomes less than the output pressure. The disk then moves upward, closing valve A and opening valve B, and allowing air to enter the output side through the ventilation port (10). (Fig. 25)

The output pressure will then increase (approaching atmospheric pressure) until it matches the set force of the spring (4). When the output pressure equals the set force of the spring (4), the disk (3) moves to close valves A and B, and a constant output pressure is maintained.

A second spring (9) is installed to improve stability by preventing vibration of the disk (3) when the difference between the output pressure and the set force of spring (4) is great. To achieve this stability, the disk (3) is always situated at the same position after the output pressure is stabilized between the idling and full speed positions.

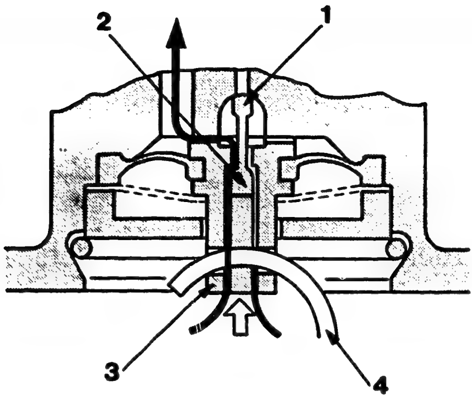


Fig. 25 V.R.V. operation (when the set force of the spring is less than the output pressure)

1 = Valve A
2 = Valve B
3 = Disk
4 = Spring

⇨: Disk movement
The disk is pulled upward by the vacuum pump, valve B is opened and valve A is closed.
➡: Air flow
Air enters the output side through the ventilation port (10), increasing the output side pressure.

COLD START DEVICE (C.S.D.)

Because engine starting in cold conditions is very difficult, the cold start device has been developed to advance the fuel injection timing to facilitate engine starting.

Construction

The C.S.D. assembly is installed on the VE pump timer's high pressure side as illustrated in Fig. 26.

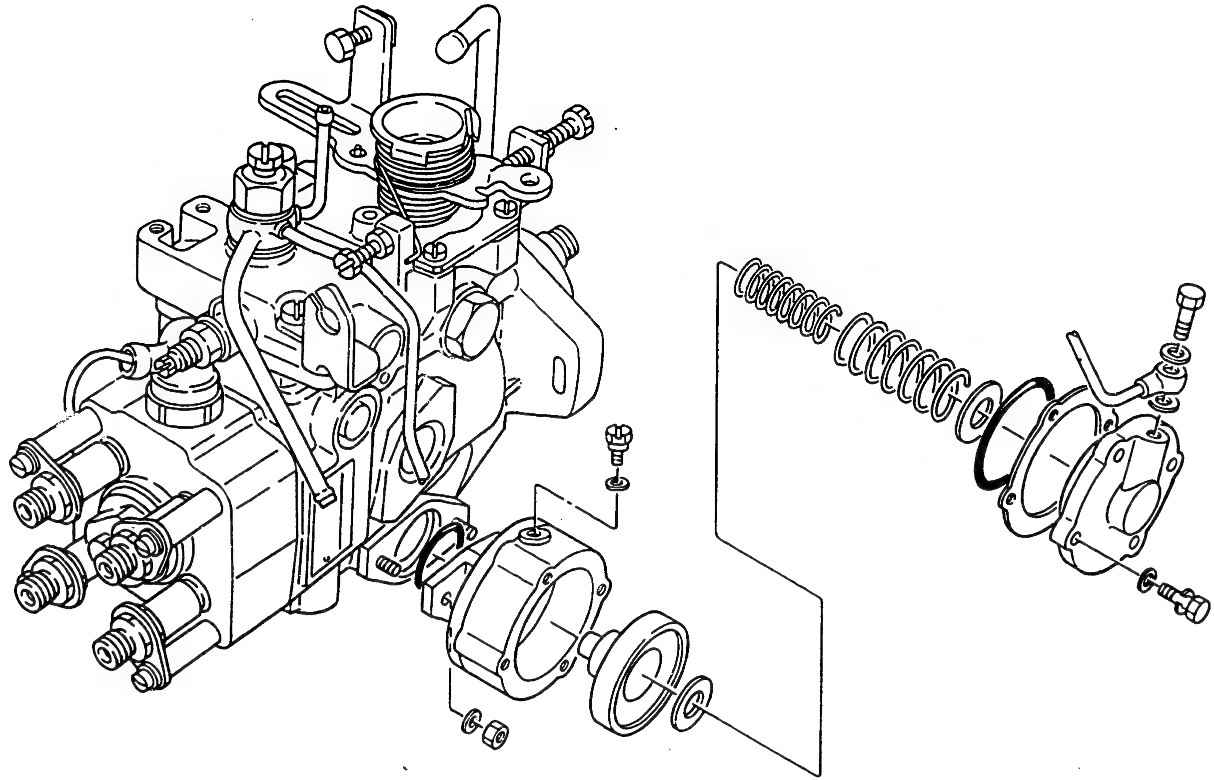


Fig. 26 Exploded view of the C.S.D.

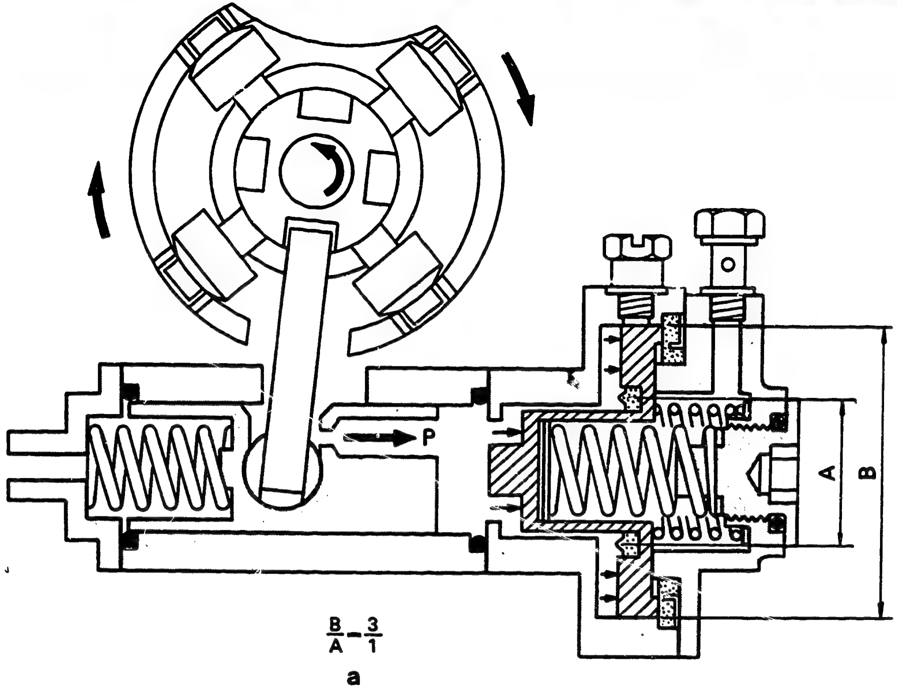


Fig. 27 C.S.D. operation a = (Surface ratio)

As shown in Fig. 27, the C.S.D. acts to advance the roller holder pin by forcing the piston towards the left (timing advance direction), through the action of the strong set force of the two C.S.D. springs.

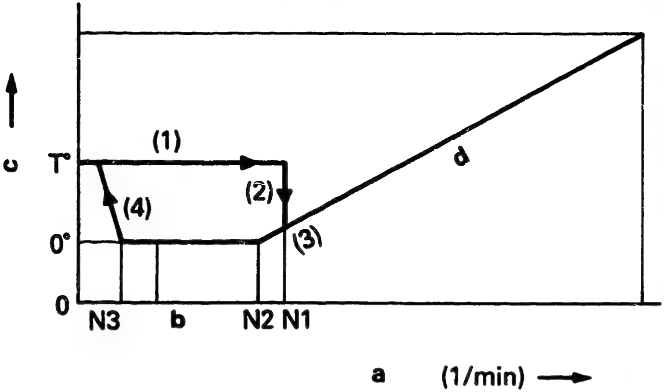


Fig. 28 Timing characteristic

a = Pump speed (rpm)
b = Idling
c = Timing advance angle (deg.)
d = Automatic advance (Normal operation)

Operation

Fig. 28 shows the range of the C.S.D. operation against the timing characteristic curve.

Range (1): C.S.D. engagement
Range (2): C.S.D. disengagement
Range (3): The timer is engaged after C.S.D. disengagement

Range (4): In this range, the C.S.D. piston's spring force exceeds the force of the fuel pressure in the VE pump housing, as fuel pressure declines with a decline in pump speed (i.e. the C.S.D. is re-engaged.)

Range (1): C.S.D. engagement

When pump speed is less than N1 rpm (See Fig. 28), the fuel pressure (P) applied to the surface area "A" in Fig. 29 is smaller than the C.S.D. springs' forces.

Therefore, the C.S.D. piston is forced in the advance direction (to the left in Fig. 29) by the force of the C.S.D. springs.

Range (2): C.S.D. disengagement

When pump speed increases to N1 rpm, the fuel pressure applied to the C.S.D. piston surface area "A" increases and balances the force of the C.S.D. springs. Therefore, when pump speed exceeds N1 rpm, the C.S.D. piston is able to compress the C.S.D spring because the fuel pressure acts on surface area "B", which is approximately three times larger than surface area "A" (as shown in Fig. 30). By this operation the C.S.D. is disengaged. Once disengaged, the C.S.D. piston remains stationary while pump speed is above N3 rpm. This is because of the ratio of surface area "A" to surface area "B".

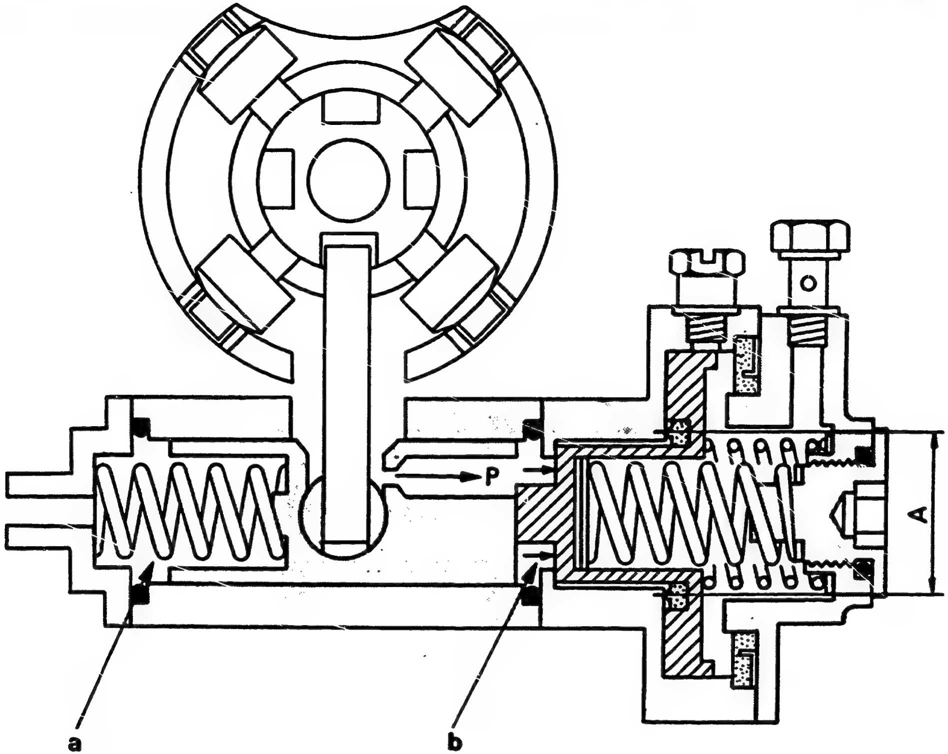


Fig. 29 C.S.D. engagement

a = Low pressure side

b = High pressure side

Range (3): Timer engagement after C.S.D. disengagement

After the C.S.D. is disengaged as described above, a normal timing advance is obtained in range (3) because of the balance between the fuel pressure applied to the high pressure side of the timer piston and the timer spring force.

Range (4): C.S.D. reengagement

When pump speed decreases through range (3) in Fig. 28 and approaches idling, the pressure applied to area "B" of the C.S.D. piston also decreases. Consequently the C.S.D. spring force will overcome the C.S.D. piston pressure, moving the C.S.D. piston to the left (See Fig. 30). The C.S.D. piston will then move the timer piston, and the injection timing will advance along range (4) in Fig. 28 until it reaches an angle of T°.

Thus the C.S.D. returns to the engaged position.

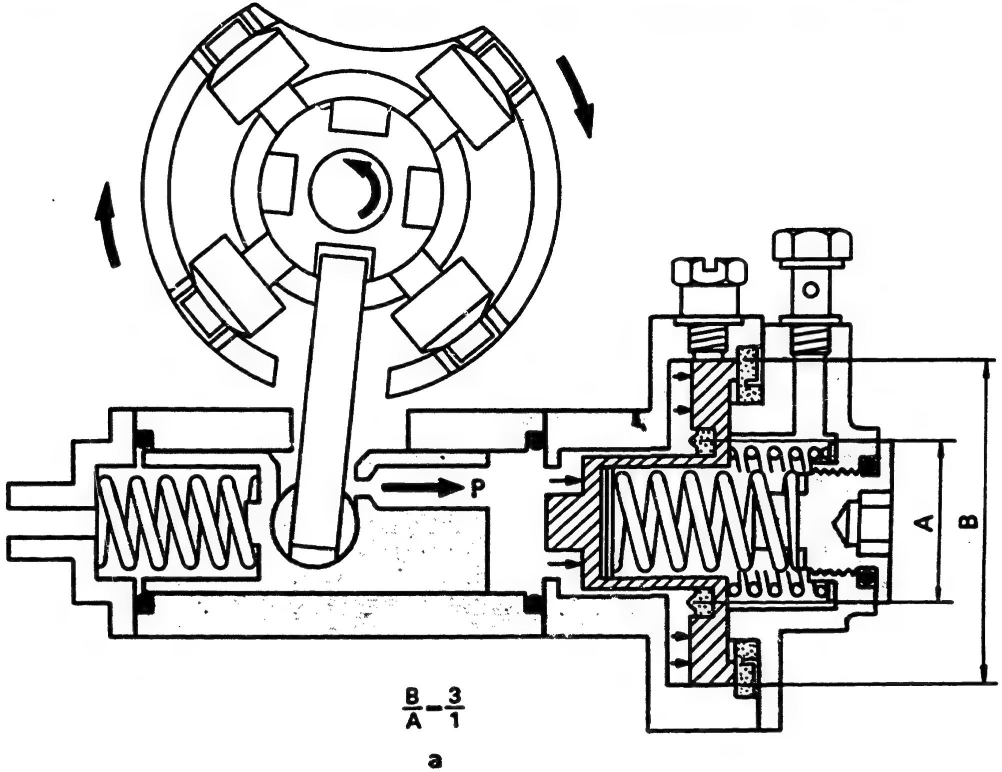


Fig. 30 C.D.S. disengagement . a = Surface ratio

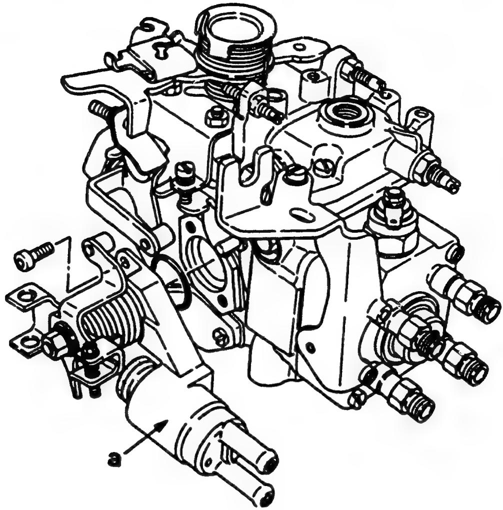


Fig. 31 Wax type cold start device (W-C.S.D.)

a = W-C.S.D.

WAX TYPE COLD START DEVICE (W-C.S.D.)

Because engine starting in cold conditions is very difficult, the W-C.S.D. (wax type cold start device) has been developed to provide the optimum fuel injection timing for engine starting by responding to temperature changes.

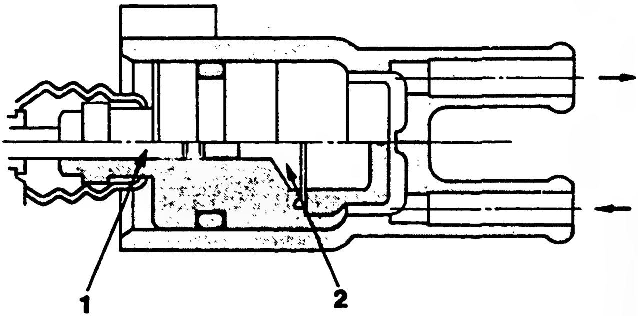


Fig. 32 W-C.S.D. body

1 = Piston
2 = Wax element

Construction

The W-C.S.D. body contains a wax element filled with wax pellets.
Cooling water circulates around this wax element, and as the wax pellets expand or contract in accordance with cooling water temperature changes, the W-C.S.D. piston is moved. (See Fig. 32)

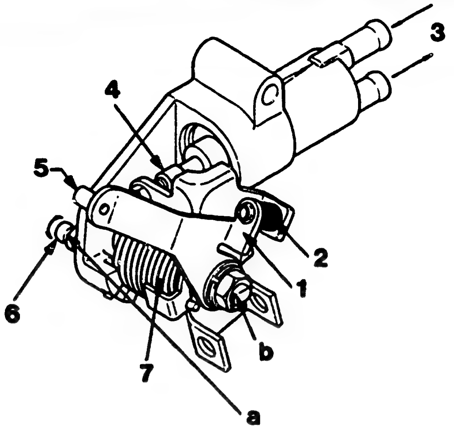


Fig. 33 W-C.S.D. operation

1 = Lever
2 = Idling adjusting bolt
3 = Cooling water
4 = Timer stroke adjusting bolt
5 = Pin (A)
6 = Pin (B)
7 = Torsion spring

a = Pump side lever
b = Out-put side lever

Piston movement rotates the lever shaft so that pin (B) on the pump side lever rotates the roller holder to advance or retard the injection timing.

Two torsion springs on the lever shaft are set so that the piston, through the lever (1), is always pushed backward (in the timing advance direction).

Besides timing advance, the W-C.S.D. also operates to increase idling speed by utilizing lever (1) movement in accordance with cooling water temperature changes, as described above.

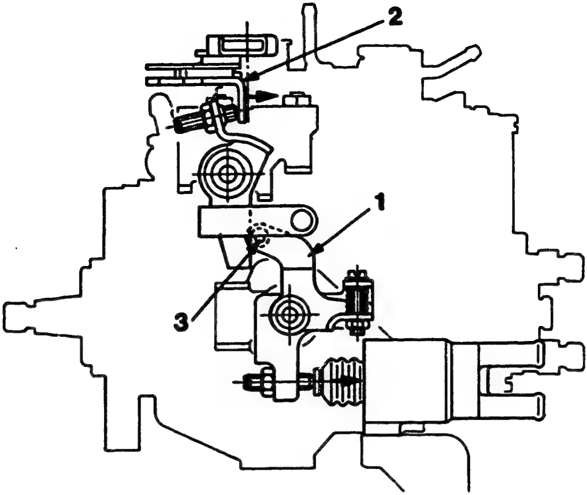


Fig. 34 Idling speed increase mechanism

1 = Lever
2 = Control lever
3 = Pin (A)

This operation is as follows:
The lever (1) is connected to the control lever through the pin (A).
When the W-C.S.D. is engaged, lever (1) movement acts to move the control lever in the fuel increase direction, thereby increasing idling speed and decreasing the time taken to warm-up the engine.

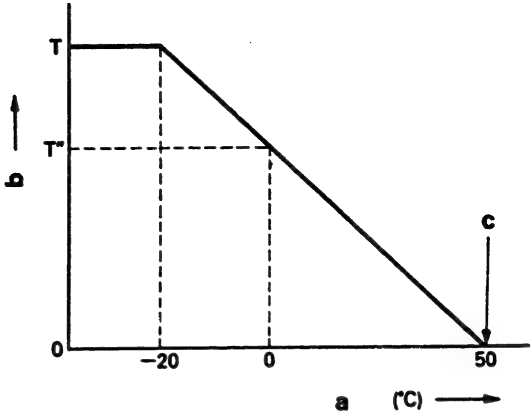


Fig. 35 W-C.S.D. performance curve

a = Cooling water temperature
b = Timing advance (deg.)
c = W-C.S.D. is disengaged

Operation

Fig. 35 shows a W-C.S.D. performance curve.
At temperatures below −20°C, the wax pellets contract and the W-C.S.D. acts so that maximum advance angle T° is obtained.
As the temperature increases above −20°C, the wax pellets gradually expand and the W-C.S.D. reacts so that the normal maximum advance angle is obtained. The expansion of the wax pellets is complete at temperatures of 50°C and above, and the W-C.S.D. is disengaged.

(1) W-C.S.D. engagement

When cooling water temperature is less than −20°C, the wax pellets contract, and the piston is moved to the right (See Fig. 36).

The lever shaft rotates clockwise (through the action of the lever shaft springs and lever (1)), moving the pump side lever, the pin (B) and therefore the roller holder in the timing advance direction.

This condition is maintained by the force of the lever shaft springs, whose force is greater than that of the timer spring.

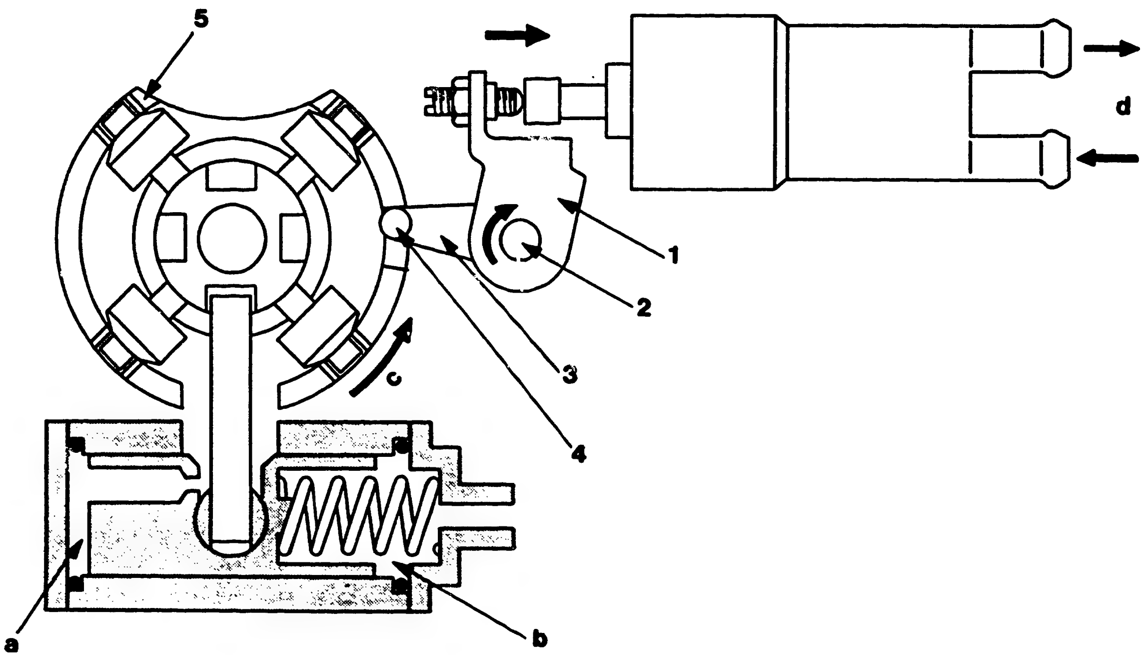


Fig. 36 W-C.S.D. engagement

1 = Lever
2 = Lever shaft
3 = Pump side lever
4 = Pin (B)
5 = Roller holder

a = High pressure side
b = Low pressure side
c = Advance
d = Cooling water

(2) W-C.S.D. disengagement

As idling speed increases and the engine warms-up, the cooling water temperature gradually increases.

As the temperature increases, the wax pellets expand and move the piston to the left (See Fig. 37).

The piston, through lever (1), moves the lever shaft and therefore the pump side lever in a counter-clockwise direction against the force of the lever shaft springs.

As fuel pressure in the pump housing is low at this time, both the action of the timer piston on the roller holder pin and the pump side lever on the roller holder move the roller holder clockwise in the timing retard direction.

Thus the staring advance angle is decreased.

When the cooling water temperature exceeds 50°C this function ceases as the control lever contacts the idling stopper bolt, and the engine speed returns to normal.

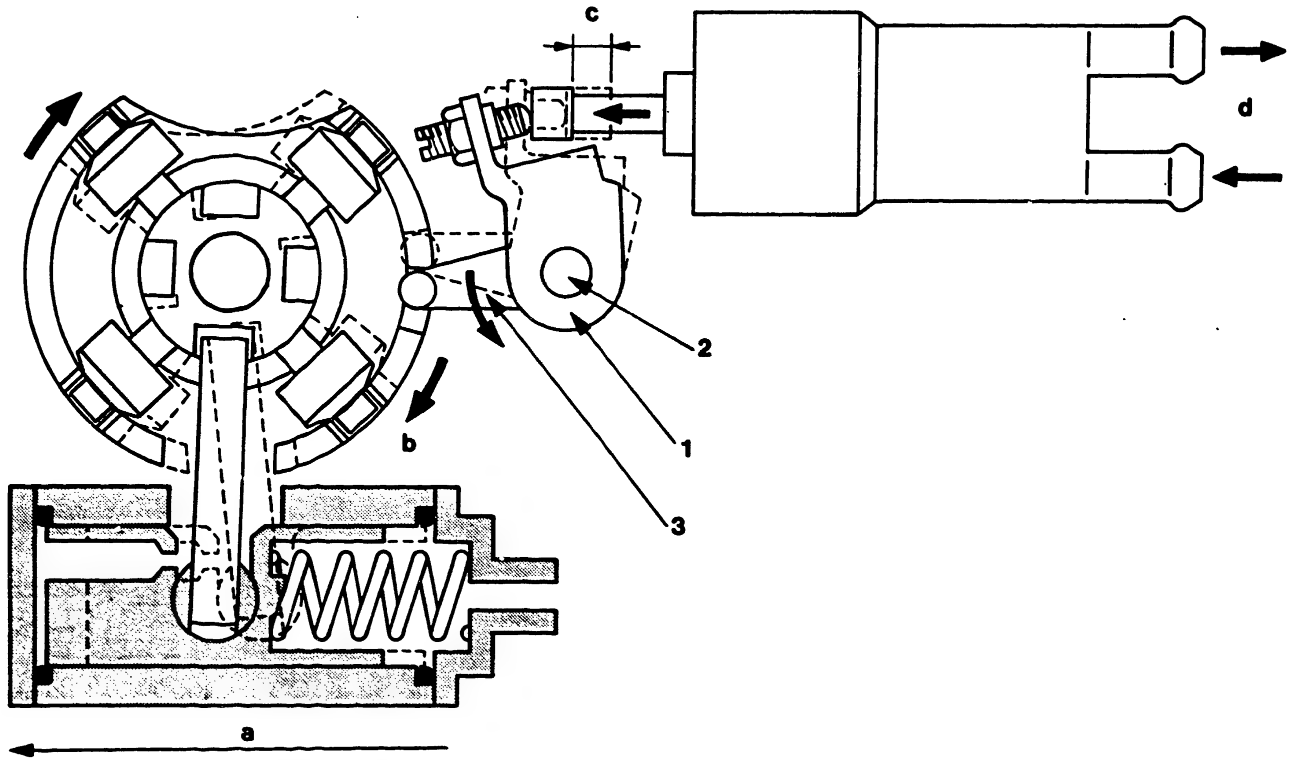


Fig. 37 W-C.S.D. disengagement

1 = Lever
2 = Lever shaft
3 = Pump side lever

a = Timing retard direction
b = Retard
c = Piston stroke
d = Cooling water

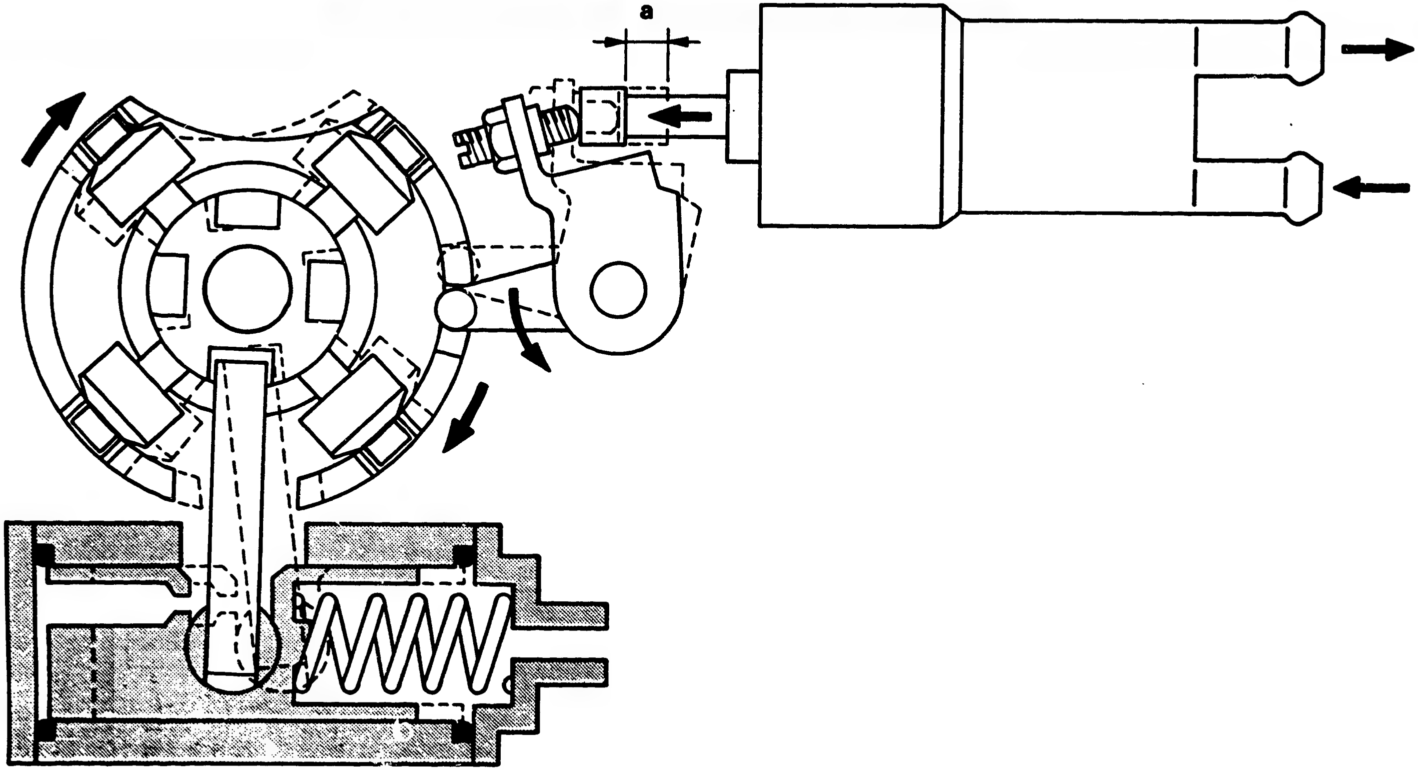


Fig. 38 W-C.S.D. disengagement a = Piston stroke

(3) Timer engagement after W-C.S.D. disengagement

As described above, the W-C.S.D. is completely disengaged when the cooling water temperature exceeds 50°C, and the engine operation is normal.
The lever shaft is stationary and the pin (B) does not engage the roller holder.

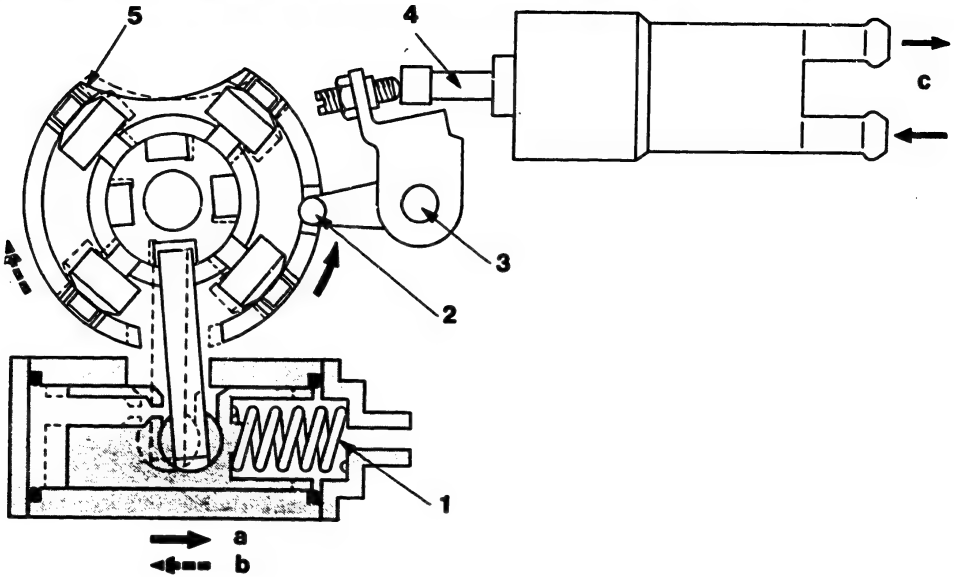


Fig. 39 Timer engagement

1 = Timer spring
2 = Pin
3 = Lever shaft
4 = Max. stroke state
5 = Roller holder

a = Advance side
b = Retard side
c = Cooling water (Temp.: above 50°C)

Therefore, roller holder movement in the advance or retard direction depends only on the balance between the timer spring force and the fuel pressure in the pump housing.

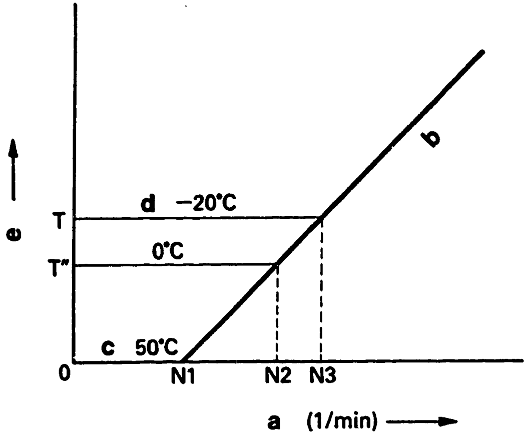


Fig. 40 Timing characteristic curve

a = Pump speed (rpm)
b = Normal timing advance
c = above
d = below
e = Timing advance (deg.)

When the cooling water temperature is below −20°C, the maximum advance angle is T° as shown in Fig. 40
However, as pump speed exceeds N2 rpm, the fuel pressure in the high pressure side of the timer also increases.

As it overcomes the timer spring force the timing advance follows the characteristic curve shown in Fig. 40.
At 0°C, the advance angle is reduced as the wax pellets are expanding and the W-C.S.D. is disengaged.
Fig. 40 also shows that the W-C.S.D. is completely disengaged only when the temperature exceeds 50°C.

(4) W-C.S.D. reengagement
The W-C.S.D. will never be reengaged during the course of engine operation once the engine has started after W-C.S.D. disengagement.
When the engine is stopped and cooling water temperature decreases from 50°C, the wax pellets start to contract and the W-C.S.D. returns the roller holder to the starting advance position in accordance with the temperature of the cooling water.
The advance angle is greatest at temperatures below −20°C.

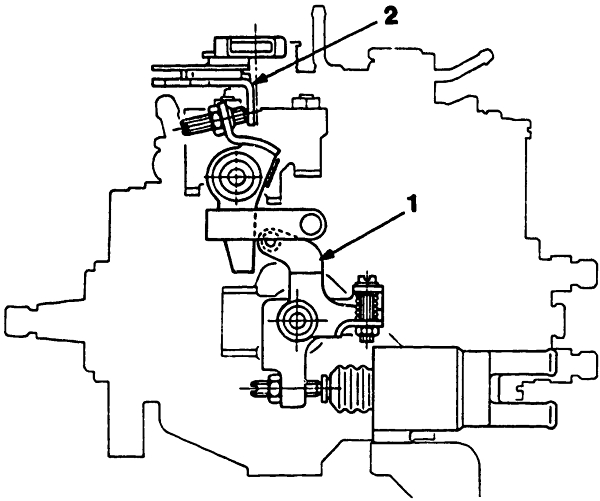


Fig. 41 Increasing idling speed

1 = Lever
2 = Control lever

The above movement is transmitted to the control lever through the lever (1), and an idling position corresponding to the cooling water temperature is automatically set. (Fig. 41)

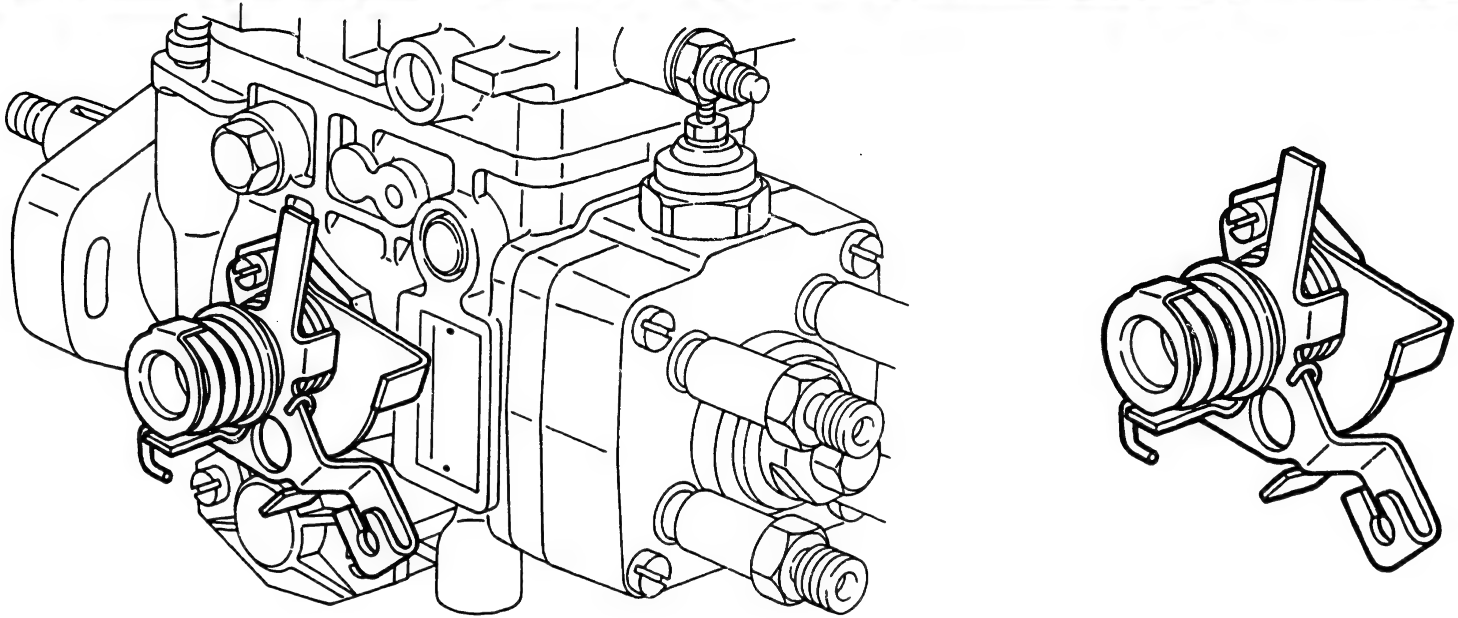


Fig. 42 M-C.S.D.

MANUAL COLD START DEVICE (M-C.S.D.)

Construction

Fig. 42 shows a standard type M-C.S.D.

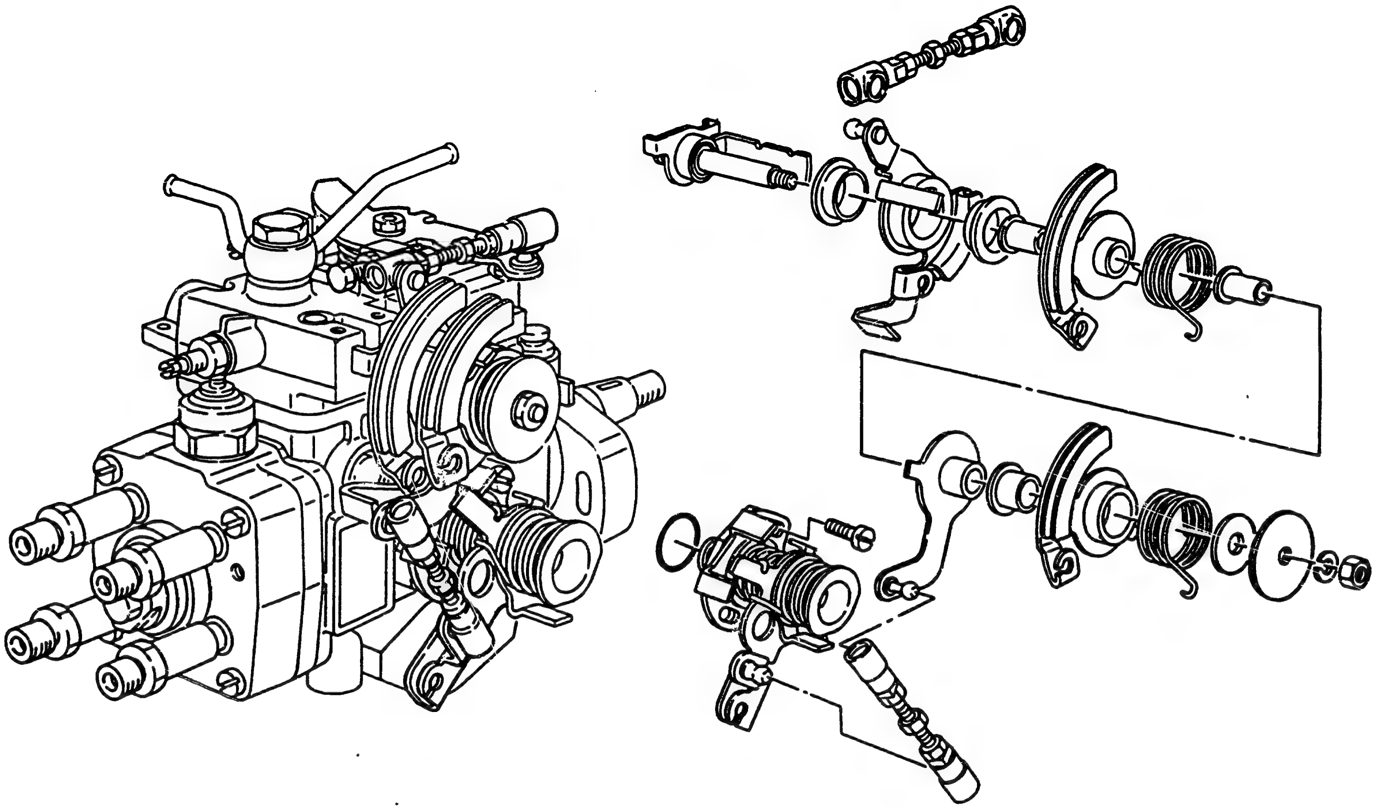
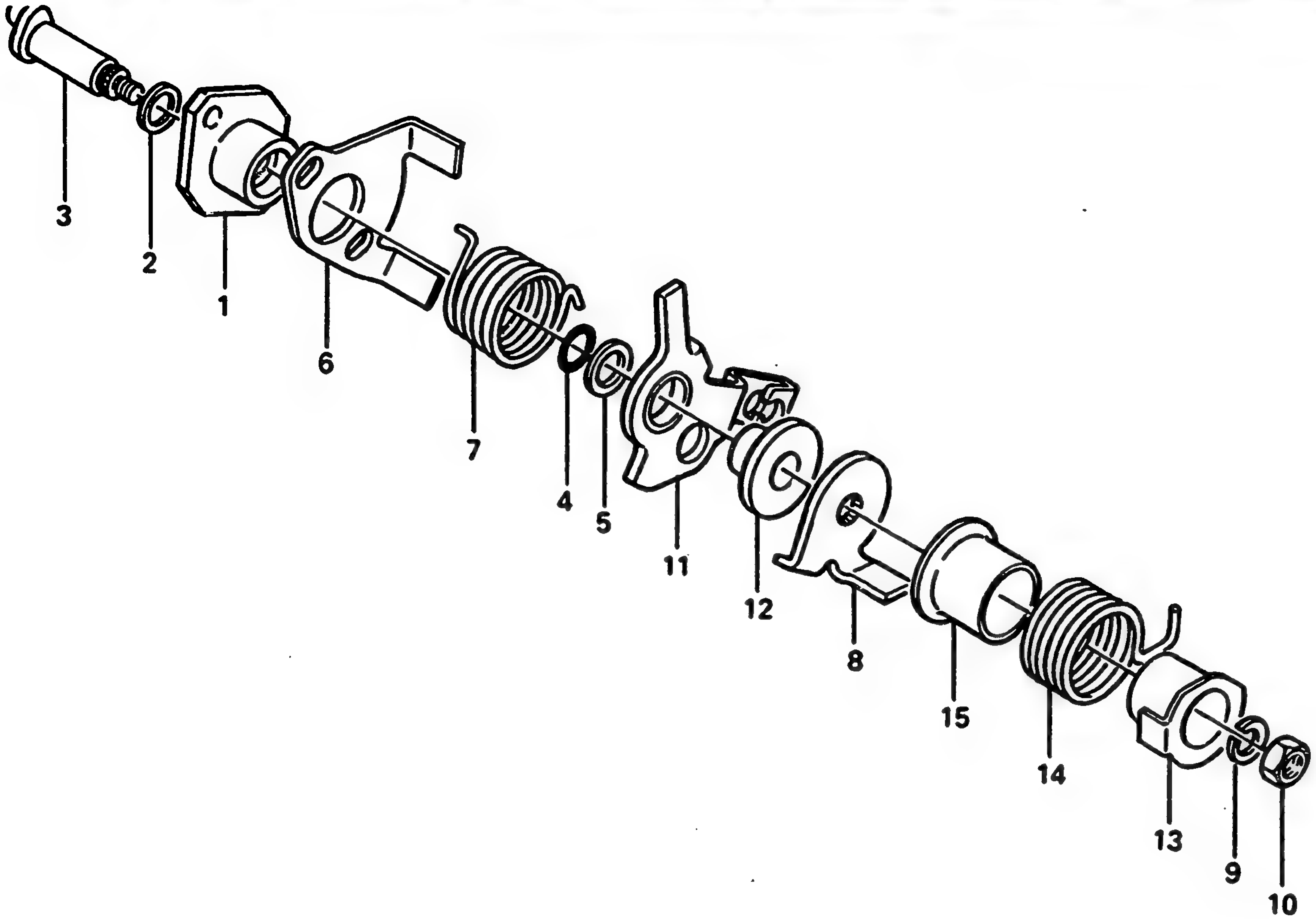


Fig. 43 M-C.S.D. (with side link lever)



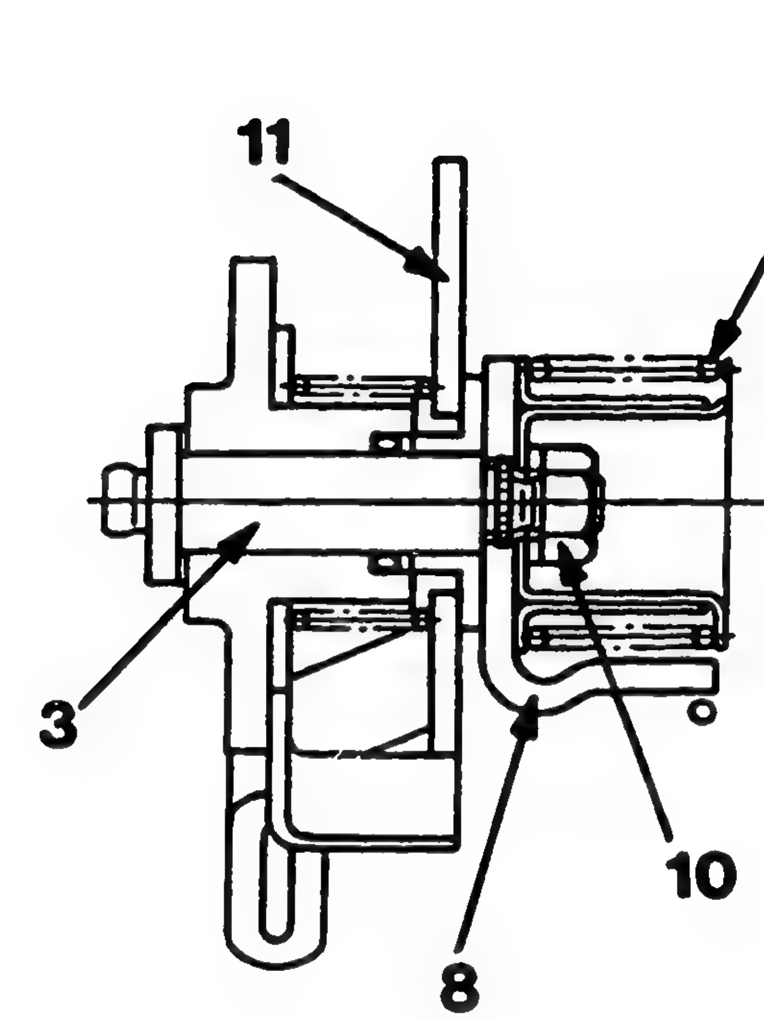


Fig. 44 M-C.S.D. operation

1 = Cover
2 = Washer
3 = Lever shaft
4 = Ring
5 = Washer

6 = Stopper
7 = Spring
8 = Plate
9 = Spring washer
10 = Nut

11 = Lever
12 = Bushing
13 = Spring seat
14 = Spring
15 = Collar

To Fig. 44:

The lever (11) is mounted on the lever shaft (3) together with the bushing (12).
The torsion spring (14), with a predetermined set force, is equipped with hooks at each end.
It is mounted with one end attached to the lever (11) and the other to the plate (8). The plate (8) is fixed to the lever shaft (3) by a nut (10).

Accordingly, when the lever (11) is moved to advance the injection timing, the lever shaft (3) is rotated by the torsion spring, and the roller holder is advanced by a ball pin located at the end of the lever shaft.
This device acts to reduce the reaction force of the lever.

Besides advancing the timing, the side link lever equipped M-C.S.D. also operates to increase idling speed by utilizing M-C.S.D. lever movement.

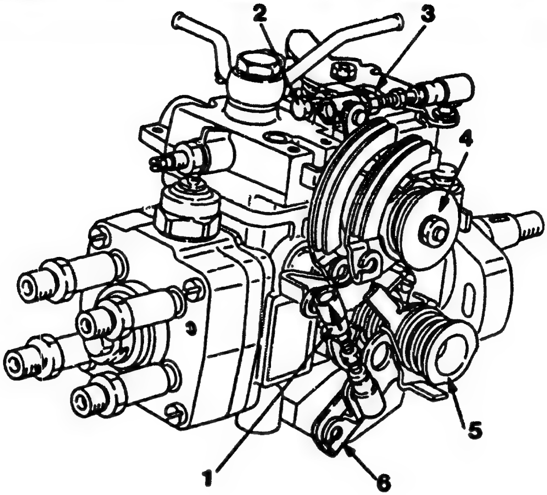


Fig. 45 M-C.S.D. operation (increasing idling speed)

1 = Rod
2 = Idling adjusting screw
3 = Control lever
4 = Side link lever
5 = M-C.S.D.
6 = M-C.S.D. lever

This operation is as follows:
The M-C.S.D. lever is connected to the control lever through the side link lever.
When the M-C.S.D. is engaged, side link lever movement acts to move the control lever in the fuel increase direction, thereby increasing idling speed and decreasing the time taken to warm-up the engine.

Operation

(1) M-C.S.D. engagement (When the M-C.S.D. lever moves counter-clockwise)

The lever shaft rotates counter-clockwise (through the action of the lever shaft springs and the M-C.S.D. lever), moving the pump side lever, the pin and therefore the roller holder in the timing advance direction.

This condition is maintained by the force of the lever shaft springs, whose force is greater than that of the timer spring.

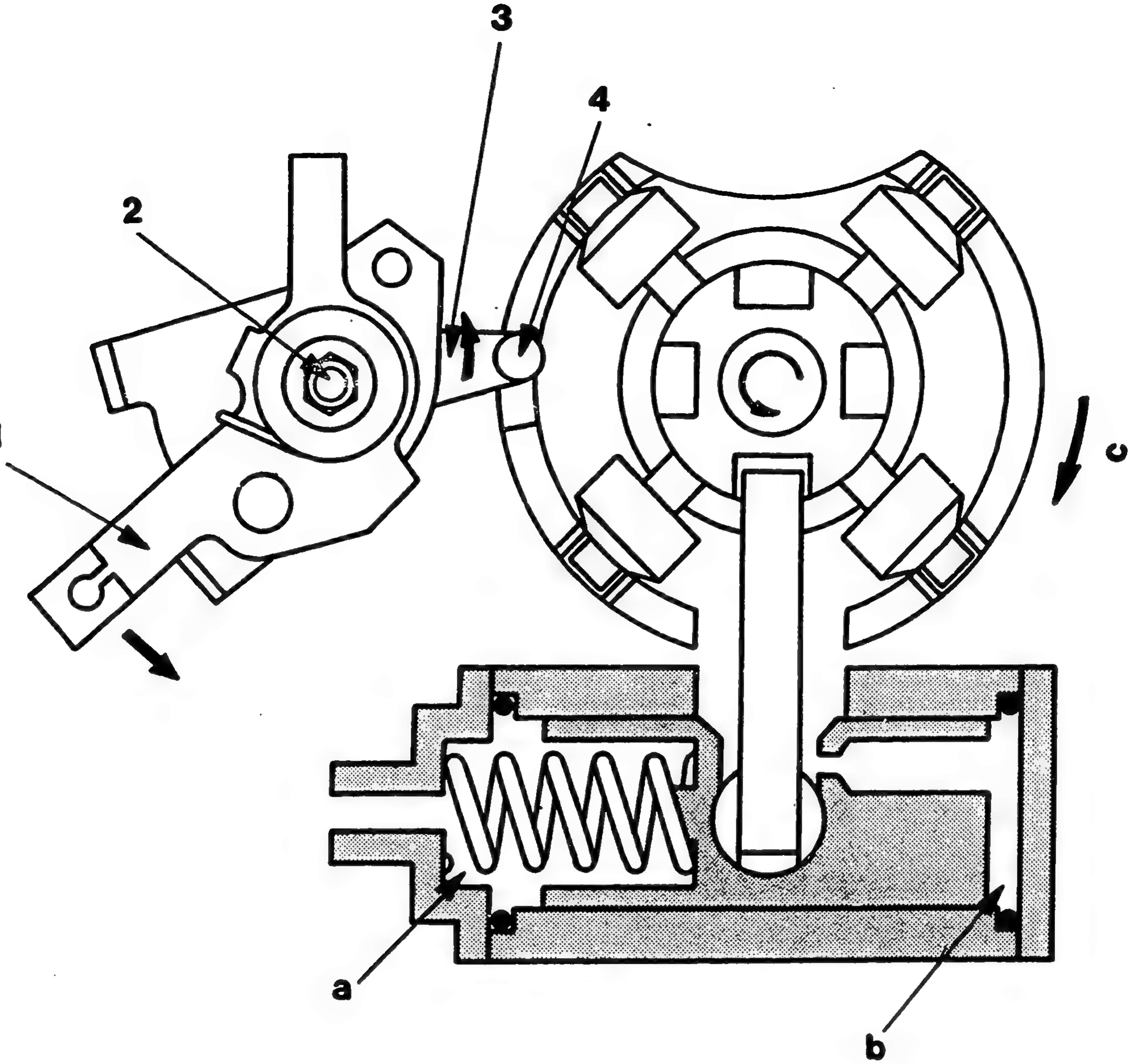


Fig. 46 M-C.S.D. engagement

1 = M-C.S.D. lever
2 = Lever shaft
3 = Pump side lever
4 = Pin

a = Low pressure side
b = High pressure side
c = Advance

(2) M-C.S.D. disengagement (As idling speed increases and the engine warms-up)

As the M-C.S.D. lever returns to its original position, the M-C.S.D. lever moves the lever shaft, and therefore the pump side lever, in a clockwise direction through the force of the lever shaft springs.

As fuel pressure in the pump housing is low at this time, both the action of the timer piston on the roller holder pin and the pump side lever on the roller holder move the roller holder counter-clockwise in the timing retard direction.

The M-C.S.D. will never be reengaged during the course of engine operation once the engine has started after M-C.S.D. disengagement.

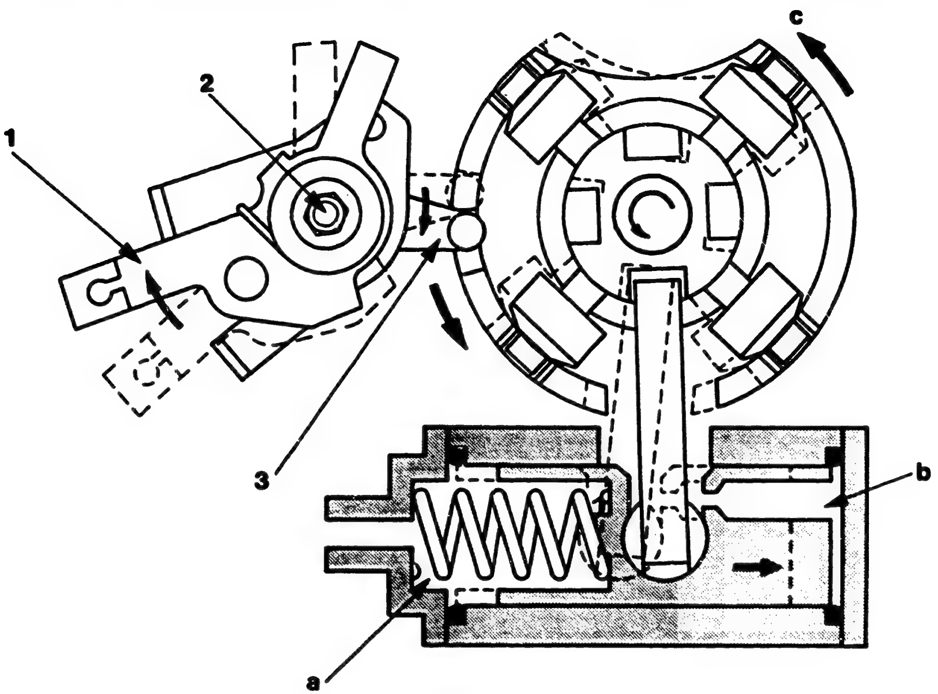


Fig. 47 M-C.S.D. disengagement

1 = M-C.S.D. lever
2 = Lever shaft
3 = Pump side lever

a = Low pressure side
b = High pressure side
c = Retard

(3) Timer engagement (after M-C.S.D. disengagement)

As described above, when the M-C.S.D. is completely disengaged and the engine operation is normal, the lever shaft is stationary and the pin does not engage the roller holder.

Therefore, roller holder movement in the advance or retard direction depends only on the balance between the timer spring force and the fuel pressure in the pump housing.

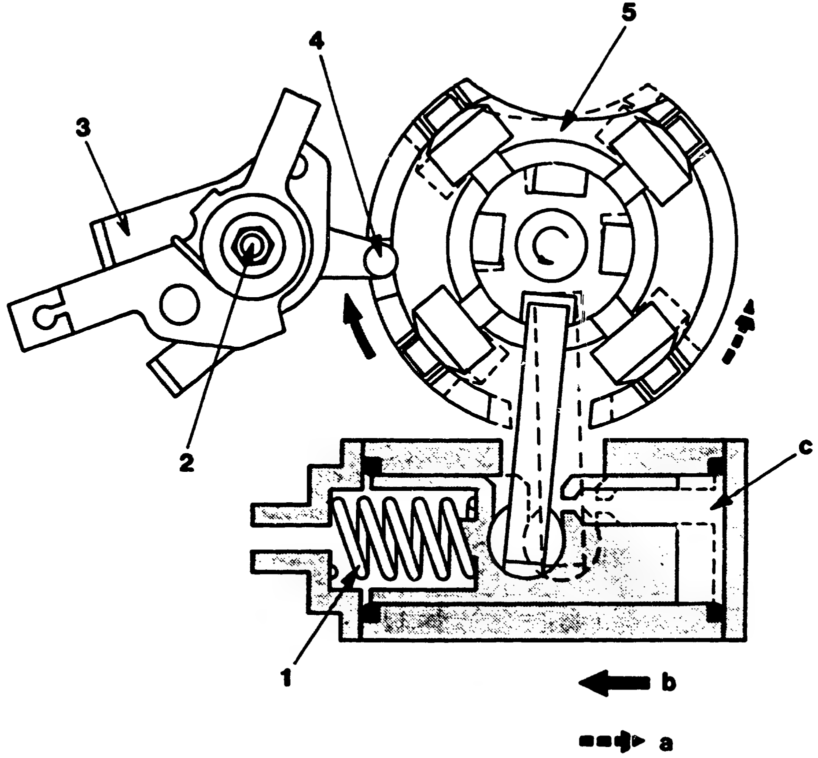


Fig. 48 Timer engagement

1 = Timer spring
2 = Lever shaft
3 = M-C.S.D.
4 = Pin
5 = Roller holder

a = Retard direction
b = Advance direction
c = Pump chamber pressure

SOLENOID TIMER

The solenoid timer (which is connected to an accelerator switch) functions to advance fuel injection timing.
The purpose for which it is used, as shown below, differs according to engine requirements.

1. To facilitate engine starting.
2. To reduce engine noise at low and medium speeds in the partial load range
3. To reduce the exhaust gas temperature at high speeds in the heavy load range.

Solenoid timer installation varies, depending on the VE pump's specifications.

Following is an explanation of the solenoid timer system's construction and operation, in regard to the solenoid timer function referred to in Item 3 above.

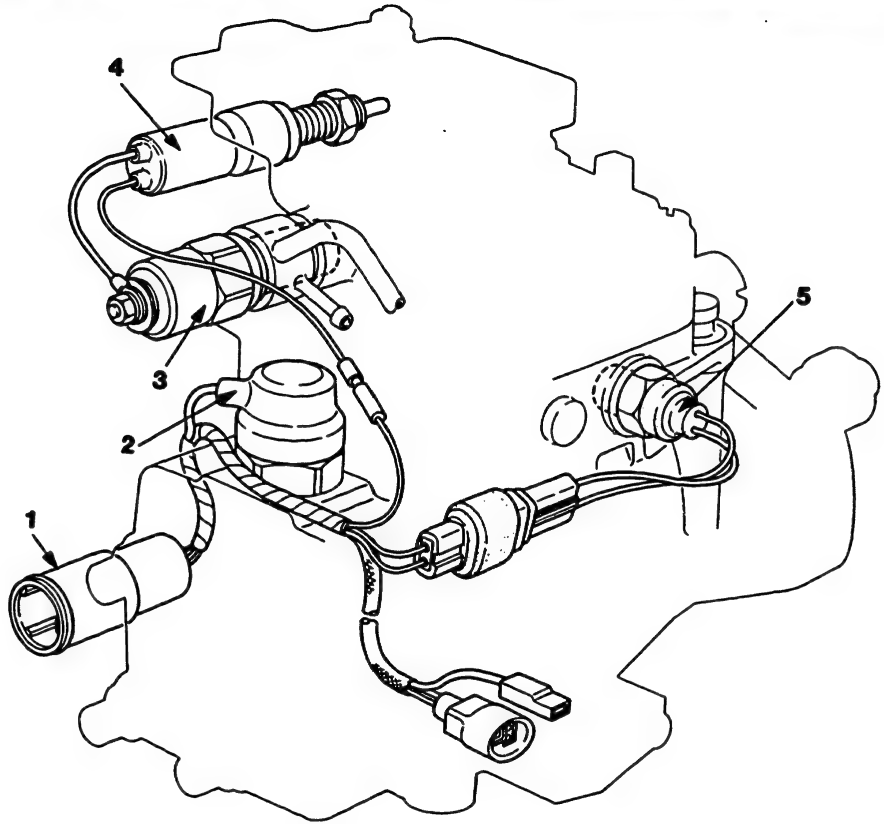


Fig. 49 Solenoid timer and accelerator switch

1 = Socket
2 = Magnet valve
3 = Solenoid timer
4 = Accelerator switch
5 = Revolution pick up

Construction

The solenoid timer is installed in the injection pump housing and, as shown in Fig. 50, is acted upon by pump chamber pressure.
It consists of a housing, a solenoid magnet, a spring and a piston. One end of the spring is surrounded by the magnet, which when activated attracts the piston to the left. The spring in the piston acts to return the piston to its original position. Two ports in the piston are open to pump chamber pressure, while two ports in the housing are connected to two fuel pipes which flow to the pump's fuel inlet. A smaller port in the housing allows excess fuel from the pump chamber to flow to the fuel tank.

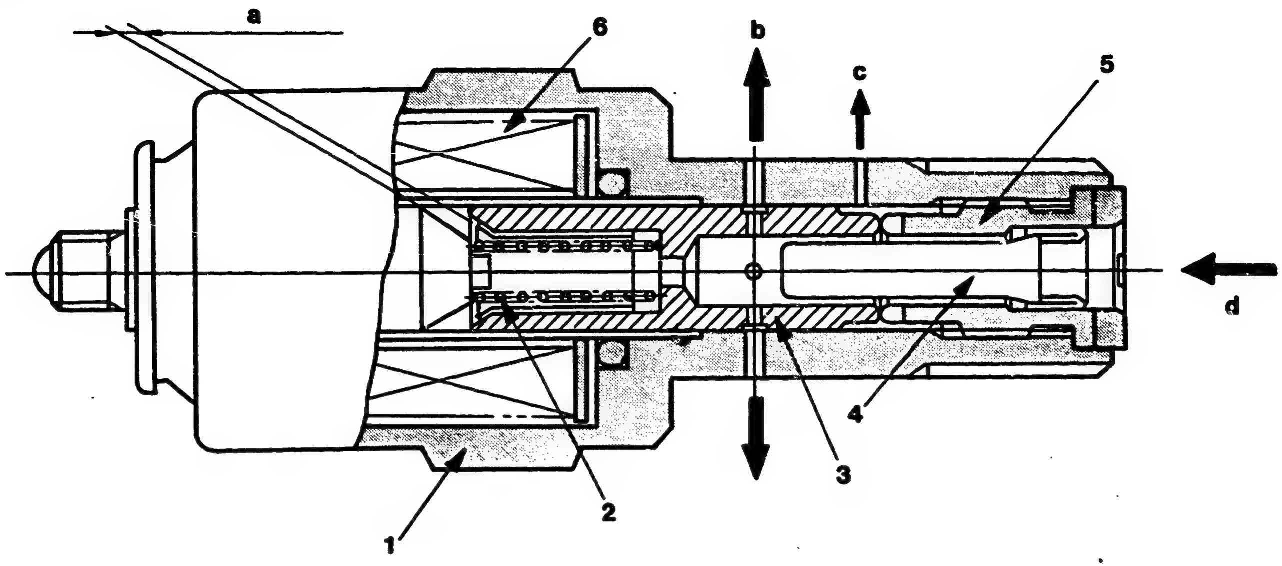


Fig. 50 Cross-sectional view of the solenoid timer

1 = Housing
2 = Spring
3 = Piston
4 = Filter element
5 = Stopper
6 = Magnet

a = Piston stroke
b = To fuel in-let on pump
c = To fuel tank
d = Pump chamber pressure

While the control lever and accelerator switch are in contact (i.e. control lever angle exceeds $\theta°$), the solenoid timer acts to increase pump chamber pressure so that the timer piston is moved in the injection timing advance direction.

Point A, where the solenoid timer begins operation, differs with engine specifications (i.e. control lever angle $\theta°$ differs).

The accelerator switch is a "normal-open" type. When the control lever is moved toward the full-speed side, the control lever angle exceeds $\theta°$ and the accelerator switch is turned ON. The accelerator switch then transmits a signal to the solenoid timer, and on receiving this signal the solenoid timer's magnet is activated and attracts the piston. When the accelerator switch is OFF, the piston is returned by the spring (see Fig. 50).

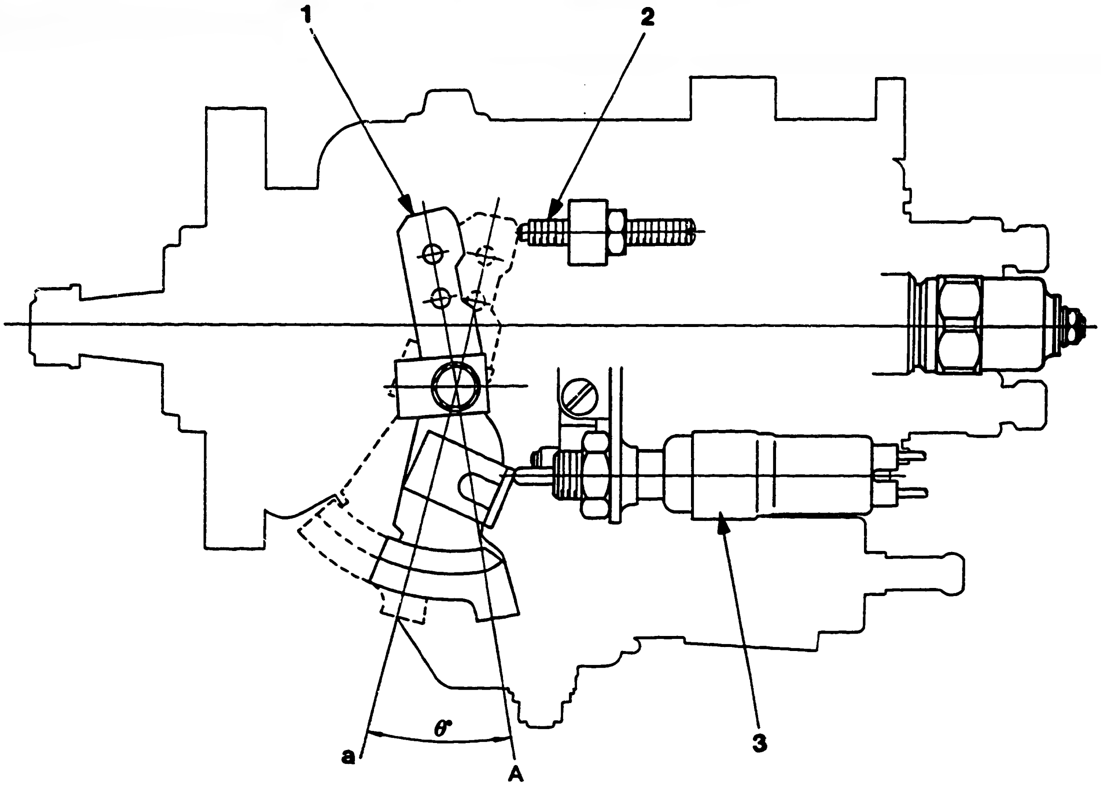


Fig. 51 Accelerator switch operation

1 = Control lever
2 = Idling adjusting bolt
3 = Accelerator switch

a = Idling lever position

Operation

1. Accelerator Switch OFF

When the accelerator switch is OFF, the piston is moved to the right (see Fig. 52) by the spring and the piston's fuel outlet is aligned with the larger of the housing's two fuel outlets. Therefore, the fuel in the injection pump overflows and is fed back to the injection pump's fuel inlet (as shown by the solid line in Fig. 52). Because of this the fuel pressure in the injection pump is kept low and the timer's advance is less than that for a normal increase in pump speed.

The smaller fuel outlet in the housing is always open, allowing overflowed fuel to be fed back to the fuel tank.

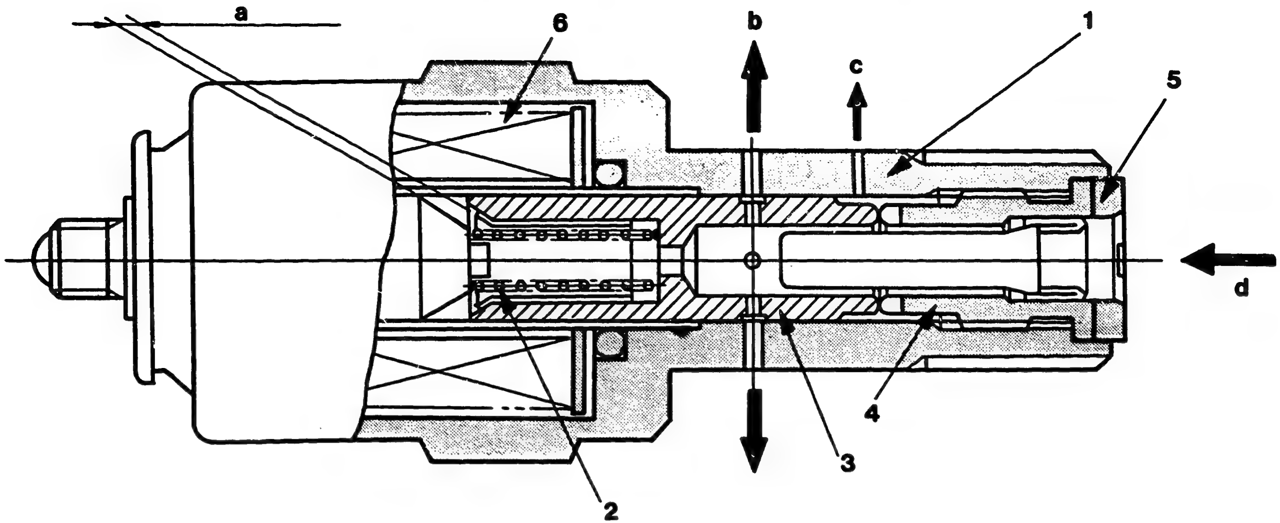


Fig. 52 Solenoid timer operation (accelerator switch OFF)

1 = Housing
2 = Spring
3 = Piston
4 = Filter element
5 = Stopper
6 = Magnet

a = Piston stroke
b = To fuel in-let on pump
c = To fuel tank
d = Pump chamber pressure

2. Accelerator Switch ON

When the accelerator switch is turned ON, the solenoid timer is activated and the magnet attracts the piston to the left (see Fig. 53), compressing the spring. Because of this the piston's fuel outlets and the larger housing outlets no longer align and fuel can not overflow from the larger openings (shown by the dotted line in Fig. 53).

Fuel in the pump therefore overflows only through the smaller outlet in the housing and the fuel pressure in the pump rapidly increases.
Consequently, the pressure in the high pressure side of the timer also increases, compressing the timer spring and advancing the injection timing.

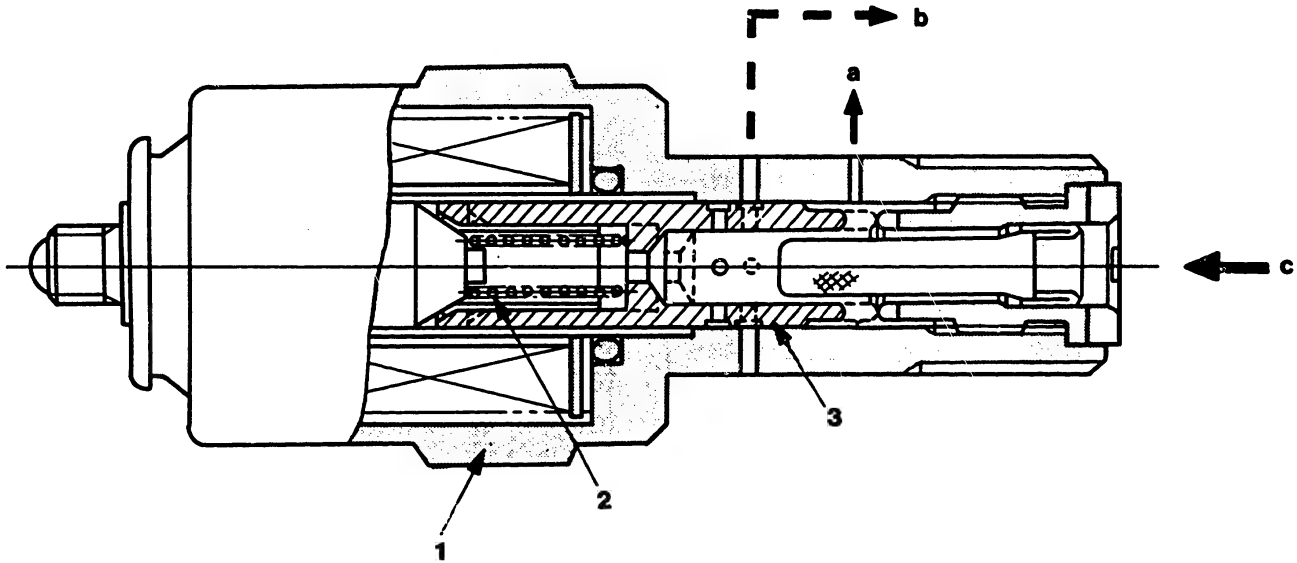


Fig. 53 Solenoid timer operation (accelerator switch ON)

1 = Housing
2 = Spring
3 = Piston

a = To fuel tank
b = To fuel in-let on pump
c = Pump chamber pressure

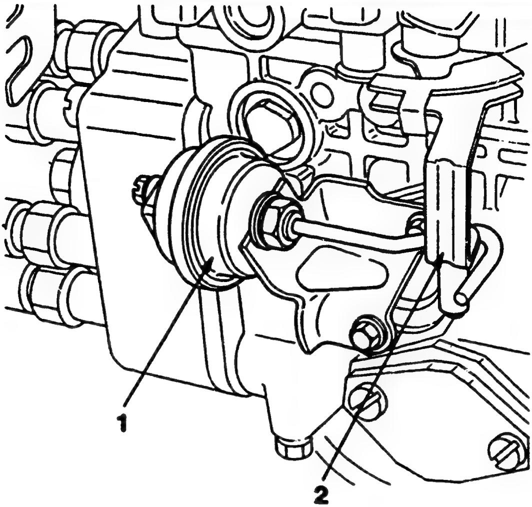


Fig. 54 Vacuum type F.I.C.D.

1 = F.I.C.D.
2 = Control lever

FAST IDLE CONTROL DEVICE (F.I.C.D.)

The F.I.C.D. is used to increase the engine's idling speed in accordance with increases in engine load due to air conditioner operation etc.
Two types of F.I.C.D. are available.

Vacuum Type

With the vacuum-type F.I.C.D., the F.I.C.D. diaphragm moves the injection pump's control lever to control idling speed.
The diaphragm itself is moved by the negative pressure generated by the engine's vacuum pump.

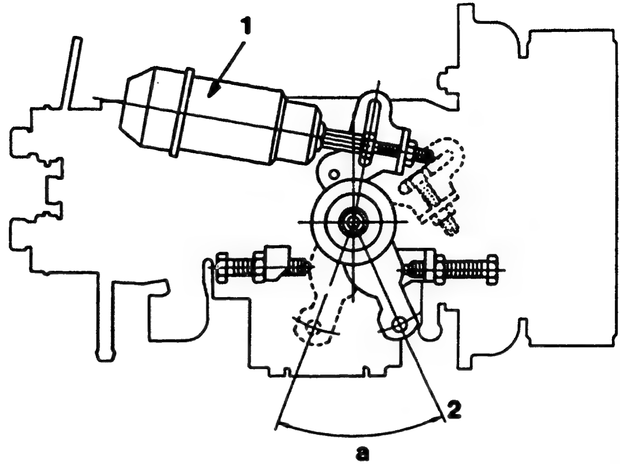


Fig. 55 Solenoid type F.I.C.D.

1 = F.I.C.D.
2 = Control lever
a = Lever operation angle

Solenoid Type

The solenoid-type F.I.C.D. is actuated by a thermo switch, which is turned ON when the engine's cooling water is less than a specified temperature.

When actuated, the F.I.C.D. moves the injection pump's control lever in the fuel-increase direction to increase engine speed.

This type of F.I.C.D. is also used to decrease the engine's "warm-up" time.

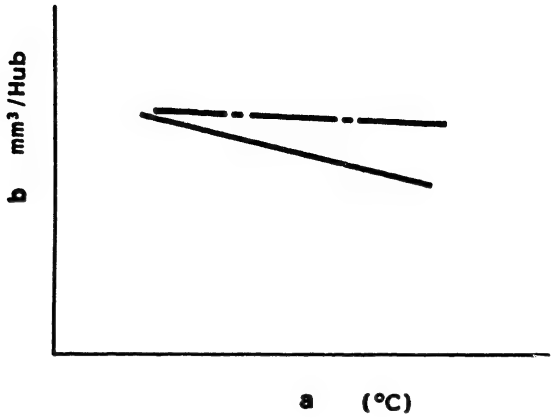


Fig. 56 Relationship between fuel injection quantity and fuel oil temperature

a = Fuel oil temperature
b = Fuel injection quantity (mm^3/st)

HIPAC (HIGH-POWER-AT-AMBIENT-TEMPERATURE COMPENSATOR)

With an increase in the temperature of fuel oil, its density decreases, resulting in a decrease in the fuel injection quantity and consequently a decrease in engine output (as shown by the solid line in Fig. 56).
HIPAC compensates for this decrease in the density of the fuel oil so that the fuel injection quantity does not decrease, even when the fuel oil temperature has increased, thus preventing a decrease in engine output (as shown by the broken line in Fig. 56).

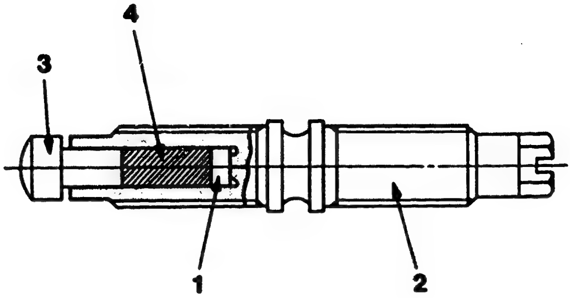


Fig. 57 Cross-sectional view of HIPAC

1 = Spacer
2 = Full-load screw
3 = Pushrod
4 = Wax pellet

Construction
A wax pellet is installed inside the injection pump's full-load screw. When this wax pellet expands or contracts, the pushrod is moved in an axial direction to vary the fuel injection quantity.
The pushrod can not be disassembled.

Operation

When the fuel oil temperature increases the wax pellet expands, pushing the pushrod out of the full-load screw (i.e. to the left in Fig. 58).

Because the pushrod is contacting the governor's corrector lever, it also pushes the corrector lever, which moves the control sleeve in the fuel increase direction to increase the fuel injection quantity and compensate for any decrease in the density of the fuel oil.

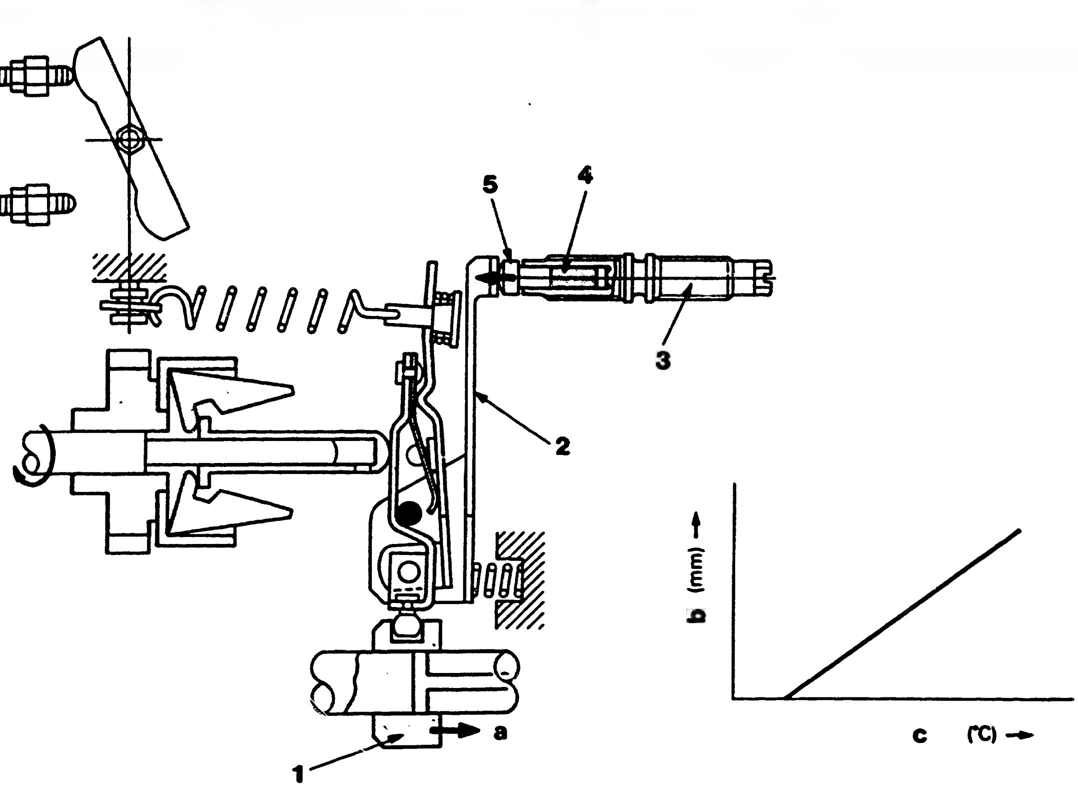


Fig. 58 HIPAC operation

1 = Control sleeve
2 = Corrector lever
3 = Full-load adjusting screw

4 = Wax pellet
5 = Pushrod
6 = Maximum-speed adjusting screw

a = Fuel increase direction
b = Pushrod stroke
c = Fuel oil temperature

DASHPOT

The dashpot is installed to prevent possible vibration of the vehicle when the control lever is moved to the idling position to bring about rapid deceleration.

Construction

As shown in Fig. 59 the dashpot consists of a valve assembly and a body assembly and is installed on the governor cover using a bracket and nuts.

The valve assembly has two air paths; A and B. Air flow through path A is controlled by an orifice, while that through path B is controlled by a plate valve.

A mesh filter is installed at either end of the valve assembly to prevent dust from entering the valve.

The body assembly consists of a diaphragm and a diaphragm spring which move together with the pushrod. During normal operation the diaphragm spring holds the diaphragm against the body assembly (Fig. 59). The diaphragm forces the air in the operating chamber out of the dashpot.

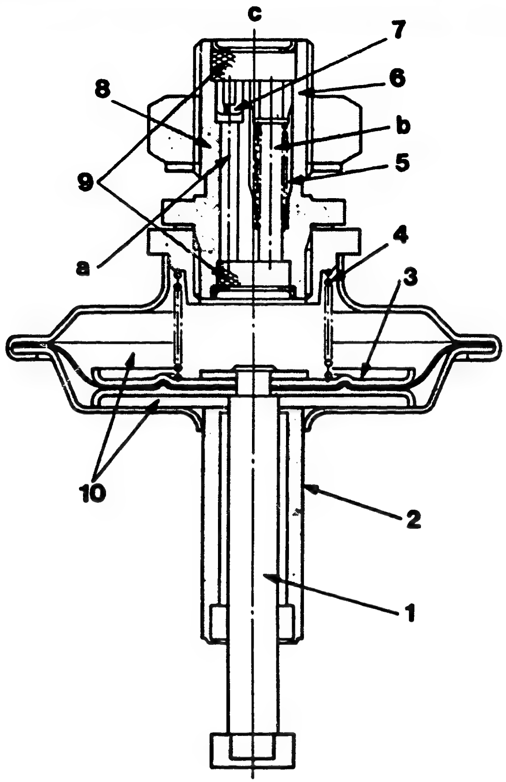


Fig. 59 Cross-sectional view of the dashpot

1 = Pushrod
2 = Body assembly
3 = Diaphragm
4 = Diaphragm spring
5 = Valve spring

6 = Plate valve
7 = Orifice
8 = Valve assembly
9 = Mesh filters
10 = Operating chamber

a = Path A
b = Path B
c = Air

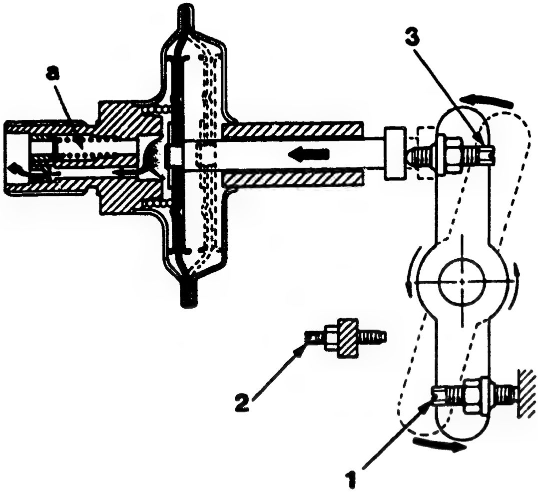


Fig. 60 Dashpot operation (deceleration)

1 = Idling adjusting screw
2 = Full-speed adjusting screw
3 = Dashpot adjusting screw
a = Path B

Operation
When the accelerator is released, the cancel spring returns the control lever to the idling position. However, before the control lever's idle adjusting screw contacts the stopper (a bracket), the dashpot adjusting screw on the control lever first contacts the dashpot's pushrod, and the control lever's return to the idling position is slowed.

1. Deceleration

As the control lever acts to return to the idling position, it pushes the pushrod, as shown in Fig. 60. The pushrod moves the diaphragm (from the dotted line position to the solid line position), which then expels the air from the chamber.

As the valve in path B opens only to admit outside air into the operating chamber, air is only expelled through the orifice in path A.

Because the orifice expels air at a controlled rate, the control lever does not immediately move to the idling position, deceleration is slowed and vibration is prevented.

2. Acceleration

During acceleration, the control lever moves from the idling position to the full-speed position and the pushrod separates from the dashpot adjusting screw as shown in Fig. 61. Therefore, the dashpot does not function during normal operation.

The diaphragm spring moves the diaphragm from the dotted line position to the solid line position, drawing air into the operating chamber through paths A and B. Because air flow through path A's orifice is limited, most air enters through path B.

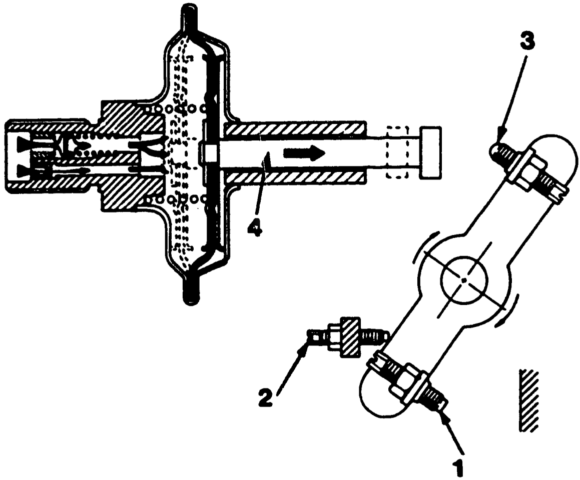


Fig. 61 Dashpot operation (acceleration)

1 = Idling adjusting screw
2 = Full-speed adjusting screw
3 = Dashpot adjusting screw
4 = Pushrod

(Continuation of coord. E 14)

As the set force of the valve spring in path B is weaker than the suction force of the diaphragm, the incoming air opens this valve, filling the operating chamber and causing the pushrod to quickly return to its original position.

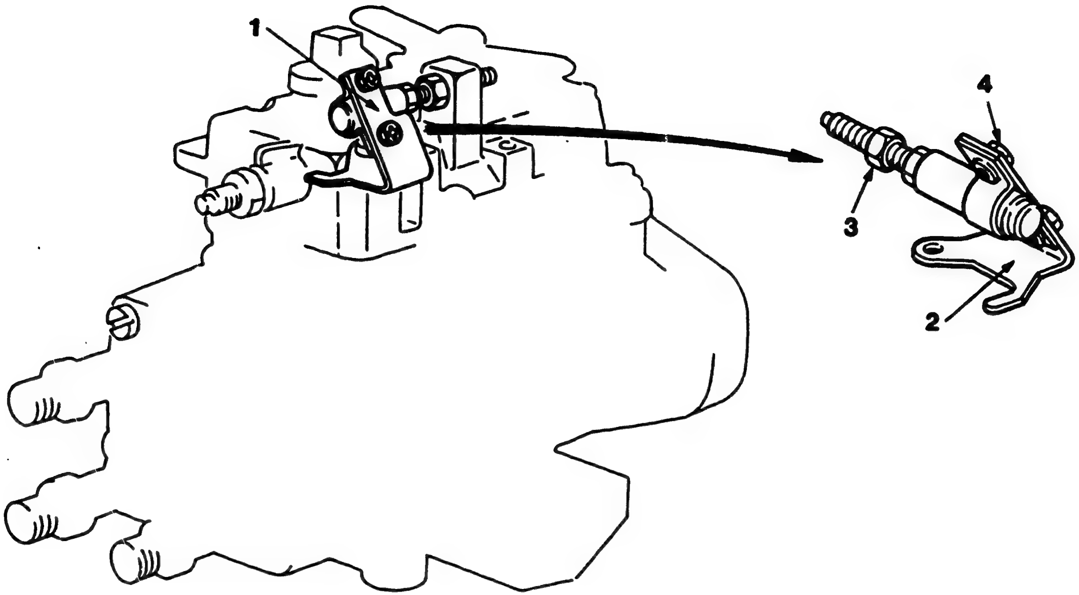


Fig. 62 Installation position of the thermostat

1 = Thermostat
2 = Bracket
3 = Locknut
4 = Bolt

THERMOSTAT

The thermostat is used to increase idling speed when the engine compartment temperature is hotter than normal.

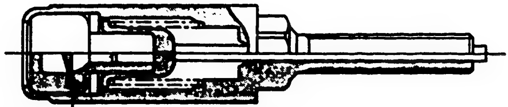


Fig. 63 Cross-sectional view of the thermostat

1 = Wax assembly

Construction
The thermostat consists of a thermostat assembly, a mounting bracket, and a locknut. The tip of the thermostat provides a stop for the control lever and thus determines idling speed.

Operation

The thermostat assembly contains a paraffin pellet that expands or contracts in accordance with changes in the ambient temperature, causing the tip to extend or retract.
An increase in the temperature of the engine compartment normally results in a reduction of the fuel injection quantity and, therefore, the idling speed.
To prevent this, the thermostat is adjusted according to the normal ambient temperature, so that when the engine compartment temperature increases, the wax pellet expands and causes the thermostat tip to extend. The tip then pushes the control lever toward the fuel-increase position to increase the fuel injection quantity and therefore maintain the normal idling speed when the engine is running hot.

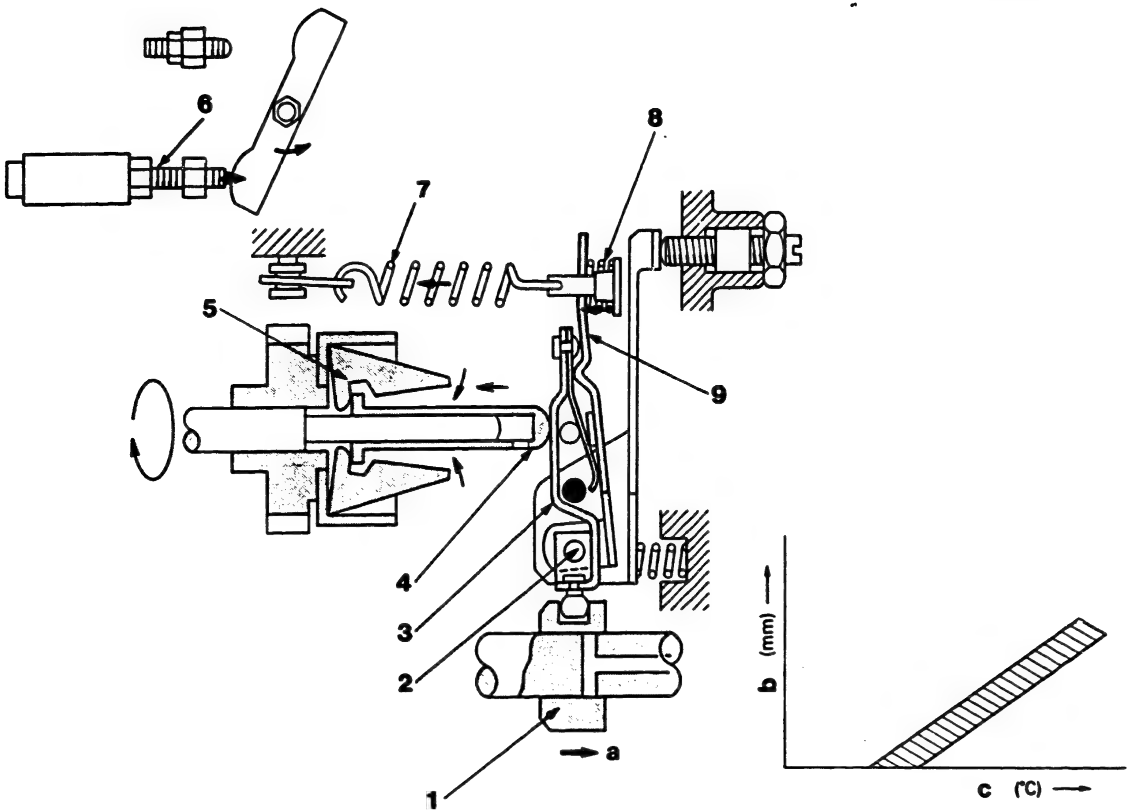


Fig. 64 Thermostat operation

1 = Control sleeve
2 = M_2 (fulcrum)
3 = Starting lever
4 = Governor sleeve

5 = Flyweight
6 = Idling adjusting screw
7 = Governor spring
8 = Idling spring

9 = Tension lever

a = Fuel increase direction
b = Pushrod stroke
c = Temperature

POTENTIOMETER

1. The potentiometer is one of the Exhaust Gas Recirculation (E.G.R.) Control System sensors.
   It helps to control the E.G.R. valve by picking up the engine load signal.

Note: The E.G.R. system is designed to control NOx emission by recirculating the exhaust gas through the E.G.R. control valve into the intake manifold. (Fig. 65)

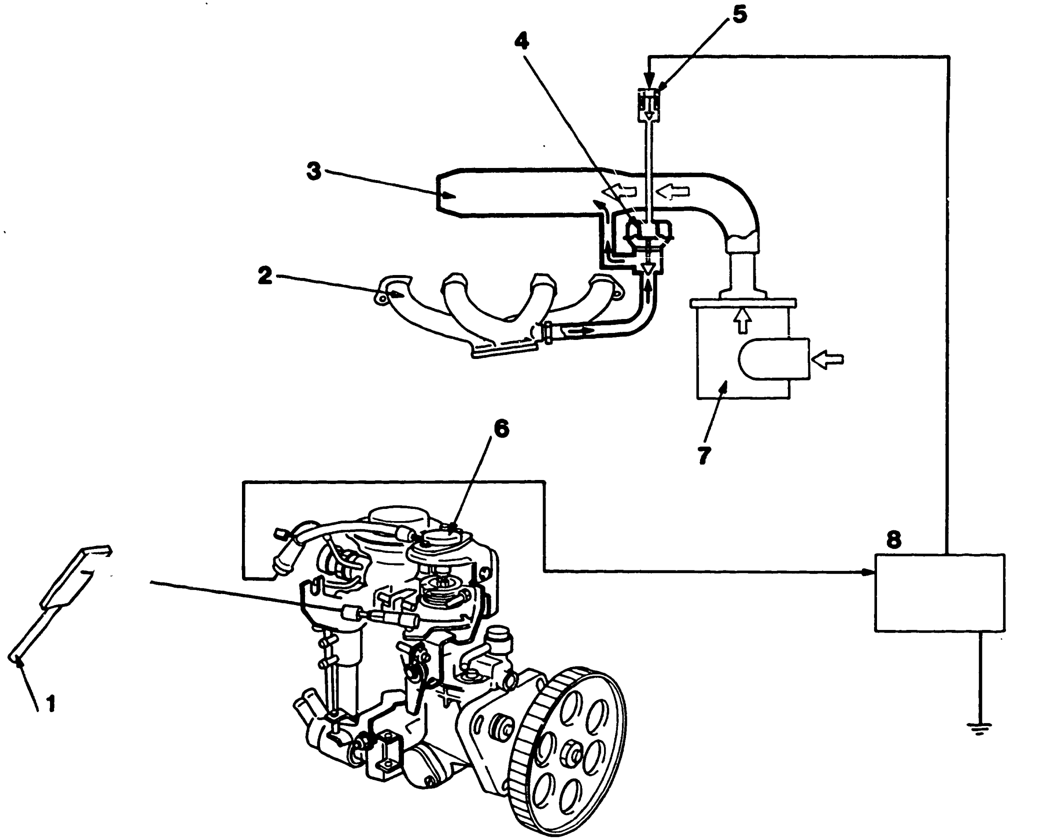


Fig. 65 E.G.R. system

1 = Accelerator pedal
2 = Exhaust manifold
3 = Intake manifold
4 = E.G.R. control valve

Note: The E.G.R. system also uses other sensors and actuators.

5 = Solenoid valve
6 = Potentiometer
7 = Air cleaner
8 = E.G.R. control unit

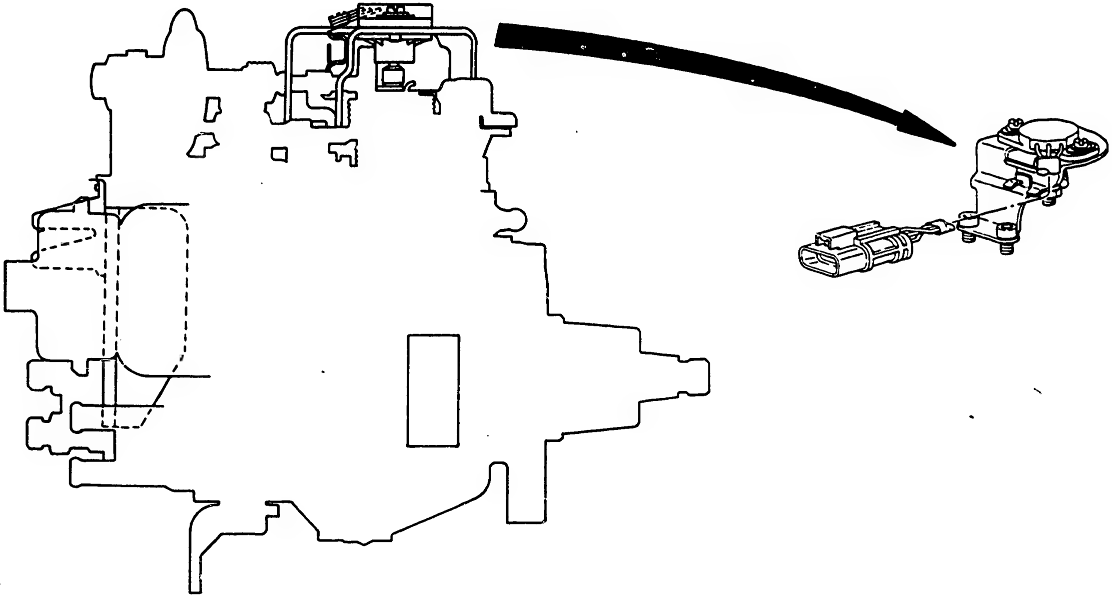


Fig. 66 Installation of the potentiometer

2. The potentiometer converts the fuel injection pump's control lever position (i.e. fuel injection quantity – engine load) into a voltage signal.

3. The potentiometer is connected to the VE pump control lever as shown in Fig. 66.

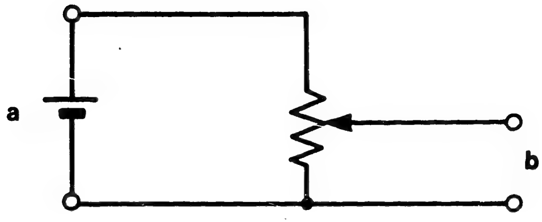


Fig. 67 Electric circuit

a = Input
b = Output

Operation
When the shaft, which is connected to the control lever, rotates, it moves an internal sliding contact along a conductive plastic (CP) resistance board. Since the output voltage changes according to the position of the contact, the position of the shaft (which equals the control lever position) can be detected. (Fig. 67)

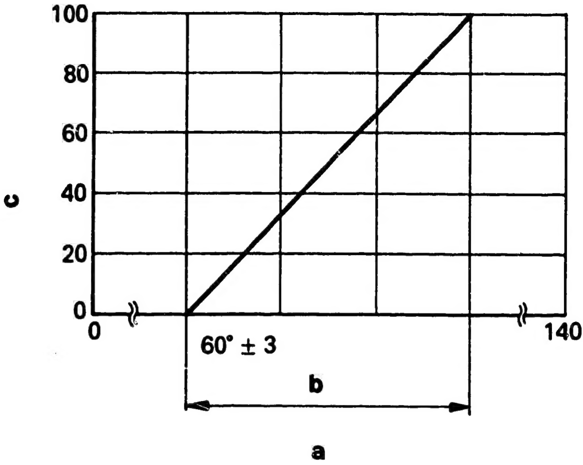


Fig. 68 Potentiometer characteristic

a = Mechanical angle (deg.)
b = Effective electrical angle
c = Output/Input voltage ratio (%)

Figure 68 shows the performance of the potentiometer.
When the rotation angle of the shaft increases, the ratio of the input voltage to the output voltage (Output V/Input V×100%) also increases.

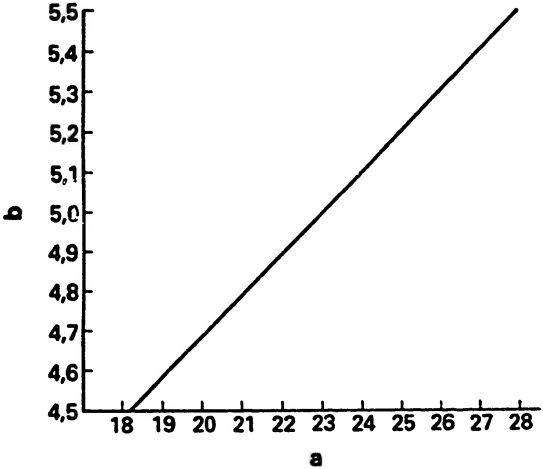


Fig. 69 Relationship between output voltage and fue! injection quantity

a = Fuel injection quantity (mm^3/st)
b = Output voltage (V)

Figure 69 shows one example of the voltage generated at the output side of the potentiometer when 10 volts is input into the potentiometer and the fuel injection quantity is varied (i.e. the control lever position is varied).
That is, when the control lever approaches the full-speed position, the potentiometer's output voltage increases.

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